Western Gray Whale Behavior and Movement Patterns: Shore-Based Observations off Sakhalin Island, July-September 2003

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INTRODUCTION, RATIONALE, AND BRIEF OVERVIEW OF RESULTS

The western population of gray whale (*Eschrichtius robustus*) is remnant and in danger of extinction (USFWS 1997, Red Book of the Russian Federation 2000, Hilton-Taylor 2000). Approximately 100 individuals habitually feed off the northeastern area of Sakhalin Island in summer-fall of every year; and considerable research on occurrence patterns, foraging and other behaviors, behavior relative to industrial activities, and genetics has taken place in the past seven years (summaries in Blokhin et al. 2003 a, b, LeDuc et al. 2002, Meier et al. 2002, Weller et al. 1999, 2002a,b, Würsig et al. 2002, 2003, Yakovlev and Tyurneva 2003, Yazvenko et al. 2002).

In 2003, we investigated spatial and temporal occurrence patterns and aspects of behavior of nearshore gray whales in proximity to potential oil/gas development by Exxon Neftegas Limited (ENL) and Sakhalin Energy (SEIC). Similar to 2002, there was considerably less vessel and other human activity in the sea than had been the case in 2001, when a three-dimensional seismic survey occurred throughout a portion of our observation period (Würsig et al. 2002). However, in 2002, there was some seismic activity being conducted by British Petroleum approximately 23 km north of the 2001 Odoptu Block and 37 km offshore around the 100 m isobath. The absence of industrial activity in 2003 provided an opportunity to observe and quantify baseline information about the natural behavior, movement, and respirations of western gray whales in their feeding grounds. As had been the case for the effort in 2001-2002, it was again decided that one platform to gauge whale behaviors would be from shore to provide long-term observations of habitat use, distribution, and behavior of gray whales nearshore. This platform had the advantage that it was some distance from the whales, thereby avoiding the possibility of the observing station(s) to be a source of disturbance. We chose three main observation techniques: 1) scan sampling to obtain relative abundance estimates, distribution, and group sizes of gray whales along shore; 2) theodolite tracking of focal groups to describe locations, orientations, speeds, and habitat usage of movements; and 3) focal group or focal animal observations to describe surfacing-respiration-dive parameters and other surface-visible behaviors. Data were analyzed by parametric and nonparametric statistical methods. Ultimately, it is our intent to describe the basic biology, behavior, and habitat utilization of these animals and the amount of variability that can exist annually, seasonally, and geographically. We understand that such baseline

information about the western gray whales will be used during project design and implementation to help design effective management strategies to protect the whales.

The 2003 field season was hampered by many poor weather days, mainly from July to mid-August, consisting of storms, rain squalls, and fog. Despite the poor weather, however, the 2003 field season was successful in providing information about movement patterns, behavioral observations, and relative numbers of whales at four geographic locations. The field season commenced on 18 July 2003 and ended on 14 September 2003. Due to weather conditions, the first day of data collection began on 22 July 2003 and the last day of effort was 13 September 2003. The season ended with 30 days of effort (233 hrs), 167 scan samples with 410 sightings, 73 theodolite tracklines, and 34 focal behavior follows of individual gray whales.

Two killer whale (*Orcinus orca*) sightings (04-September-2003 and 07-September-2003) were made in our nearshore study area during the 2003 field season.

METHODS

Methods used in 2003 were consistent with those implemented in 2001-2002, and much of this section is repeated from Würsig et al. (2002) and Würsig et al. (2003), with variations in some analyses, as given below.

Study Area

Shore-based observations were conducted along 32 km of coastal region in the northeastern portion of Sakhalin Island, Russia (Fig. 1). The study area encompasses one nearshore part of the only known feeding ground off northeastern Sakhalin Island for the western (or Korean-Okhotsk) stock of gray whales, with an apparent nutrient-rich habitat that may be influenced by a local lagoon ecosystem, known as Zaliv Pil'tun (see also Johnson 2002). The nearshore waters of the Sea of Okhotsk are characterized by sand substrate with a gradually sloping continental shelf.

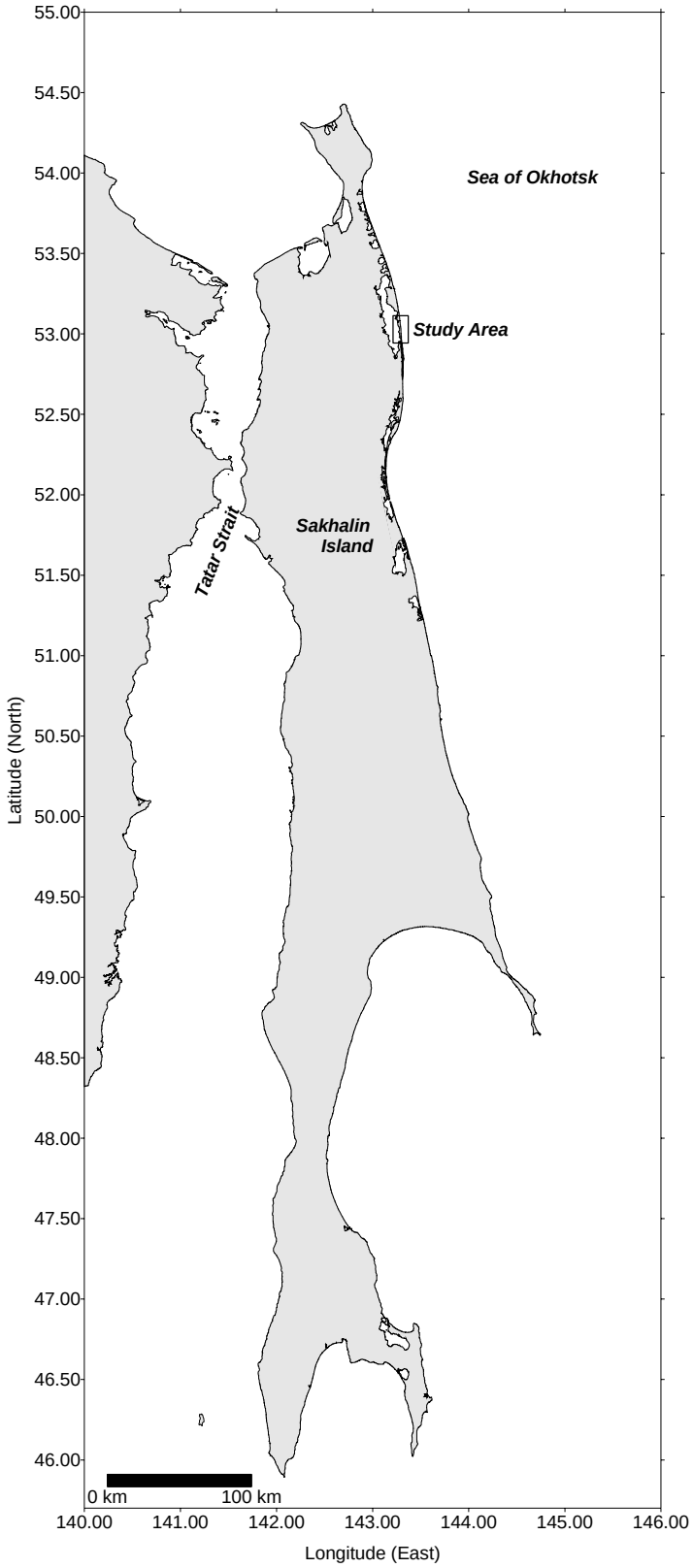


Figure 1. Study area in the northeastern portion of Sakhalin Island in Far East Russia.

Shore-Based Observations

Four geographic locations were chosen to conduct behavioral observations on western gray whales during the summer of 2003 (Table 1). Each station was selected based on its height above sea level relative to the generally low dunes of the area (Table 1), and overlapping distance (approx. 4 km) to other shore-based stations (Fig. 2). The position of each station allowed the shore-based team to monitor gray whale behaviors along 32 km of coastal region. Due to the logistic difficulty of moving between stations, one day of effort was usually dedicated to one of the four shore-based stations. A station was selected to proceed systematically from south to north. Once the northern-most station was reached (Odoptu Station), then the next day of effort would continue at the most southern station (1st Station). Two stations (2nd Station and Station 07) had also been used during the 2001 seismic study; 1st Station and Odoptu Station were first used in 2002.

Table 1. Four shore-based vantage points along the northeastern coast of Sakhalin Island, Russia. Station height is at mean low water.

Station Name	Latitude (N)	Longitude (E)	Station Height (m)
1st Station	52° 58' 27"	143° 18' 07"	10.1
2nd Station	53° 03' 08"	143° 17' 04"	8.6
Station 07	53° 07' 29"	143° 16' 12"	8.1
Odoptu Station	53° 12' 33"	143° 14' 51"	17.2

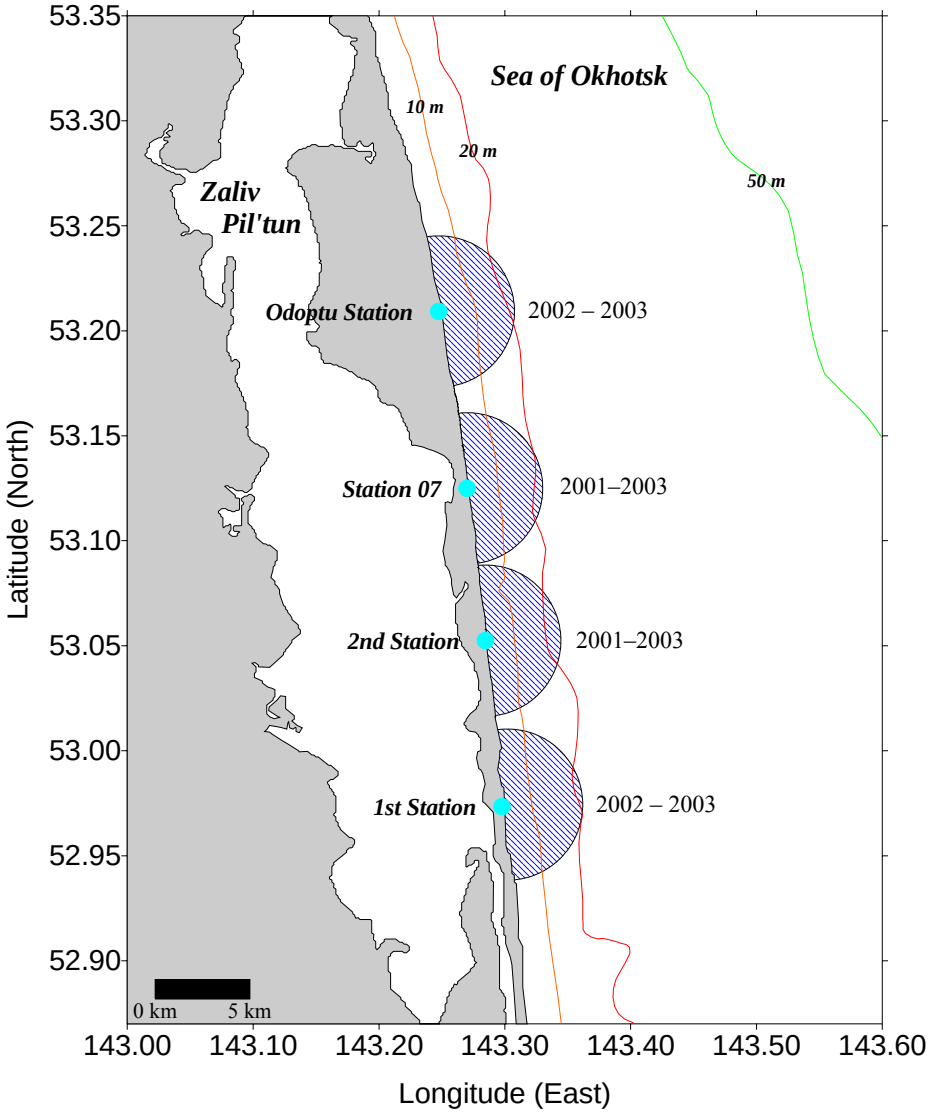


Figure 2. Geographic positions of four shore-based stations along the Odoptu Block in the northeastern coastal region of Sakhalin Island, Russia. Semi-circular grids illustrate approximate viewable range (4 km) from each shore-based station. Years indicate data collected at each station during the period of time specified.

Environmental Considerations

Environmental conditions were recorded several times per day to ensure consistent and reliable results for all three methodological techniques employed by the shore-based monitoring team (see below). The relative visibility, glare concentration and horizontal angles, sea state (Beaufort scale values of 0-4 were recorded in this study, with 3 being small whitecaps and > 3 generally unacceptable for most analyses except for movement patterns

and when whales were < 2 km from the observation point), wind direction, cloud cover, and swell environmental conditions were recorded. A hand-held weather station was utilized to automatically record temperature, barometric pressure, wind speed, humidity, and several other environmental parameters at 10-min intervals throughout each day of effort. After each field day, the environmental data were downloaded to a PC and stored for later use. If any of the above-mentioned environmental parameters hampered observations, then research effort was discontinued until conditions were acceptable.

Scan Sampling

To monitor the relative number and distribution of gray whales in the study area, scan sampling methods were conducted hourly when focal behavior sessions were not being conducted. Two observers used hand-held binoculars (7x50) to scan a predetermined section of the study area ranging from 20° to 160° magnetic North (magnetic declination relative to true North =12.19°West). Each scan was initiated from the northern portion of the study area and proceeded to the southern portion. The duration of each scan was 15 min, with a maximum of one scan per hour. Once an observer sighted a whale or whales, we recorded the number of whales, magnetic bearing, reticles (etchings inside the binoculars used to estimate distances by known sizes of objects in view, or angle below horizon), and the observer's impression of distance from the study site.

Theodolite Tracking

The spatial and temporal movement patterns of gray whales were monitored with a Lietz/Sokkisha Model DT5A theodolite with 30-power monocular magnification and 5-sec precision. This technique converts horizontal and vertical angles into geographic positions (latitude and longitude) for each theodolite recording. The tracking of individuals over time provides information about the animals' relative speeds and orientations, alone or in relation to seismic or other human activity on the water (see Würsig et al. 1991, Gailey 2001, Gailey and Ortega-Ortiz 2002, and Appendices 1 and 2, for further description and mathematical calculations used in this methodological technique). A theodolite tracking session was initiated when a single or an individually recognizable gray whale in a group could be identified and the individual was within a relatively close distance (< 4 km) from the shore-based station. Each individual was continually tracked until the animal was lost, moved

beyond the 4 km critical distance, or when environmental conditions hampered further tracking. For each theodolite recording (subsequently referred to as a fix), the date, time, and vertical and horizontal angles were stored in a Microsoft Access database with the relative distance, bearing (referenced to true North), and geographic position calculated in real-time by the theodolite computer program *Pythagoras* (Gailey and Ortega-Ortiz 2002). Due to the relatively low elevations of each station, a maximum of 4 km distance from the station was used for a critical distance to ensure reliable data for analysis, such as speeds, orientations, and displacement (see page 4, Table 1, for station elevations and Würsig et al. 1991 for height-related errors).

Focal Behavior Observations

Focal behavior sessions (Altmann 1974, Martin and Bateson 1993) were conducted on individual gray whales to determine if any behavioral or respiration changes occurred in relation to environmental variables. However, a complete set of environmental data was not available for analysis in this report, and such analysis is not conducted here. A focal behavior session was initiated when all observers determined that a single whale could be monitored continuously and reliably enough so that respiration and critical behavioral events would not be missed. The reason for choosing a single whale was that it was generally impossible to distinguish known individuals, due to our low vantage point and distance from whales. A focal session would be terminated once the whale moved out of the study area or when the above conditions were not met. At least one behavioral observer would follow individuals with the aid of hand-held binoculars (7x50). The behavioral observer would call out each behavioral event that occurred, and this information along with information about date and time were recorded by a computer operator into a laptop computer and analyzed with Pythagoras. To minimize inter-observer variability, the behavioral observer's observations were periodically evaluated by other observers. In most focal follow sessions, behavioral/respiration events could be recorded simultaneously with spatial and temporal movements of the focal animal.

Data Analysis

Scan Data – For a broad overview, the relative number of whales and number of pods were analyzed. All scan-based data were evaluated for the entire coastal region observed

throughout the four shore-based stations and within and between each station. The number of whales/pods per station were also evaluated at different time periods of each day of effort. Due to non-normal distribution of the scan data, both the number of whales and pods were transformed (log (# whales or pods +1)) for analytical purposes. Based on the observed height above sea level, geographic bearing, and reticle readings of each sighting, distance from observer and geographic location was calculated (see Lerczak and Hobbs, 1998 for distance equations). A refraction index was used to correct for potential errors in line-of-sight estimation within the distance approximation (Leaper and Gordon, 2001). Due to differences in observation heights at the four stations, a threshold of < 6 km distance from the station was used for some analyses (i.e. comparing relative abundance values between stations) in order to fairly compare between different stations (Fig. 3).

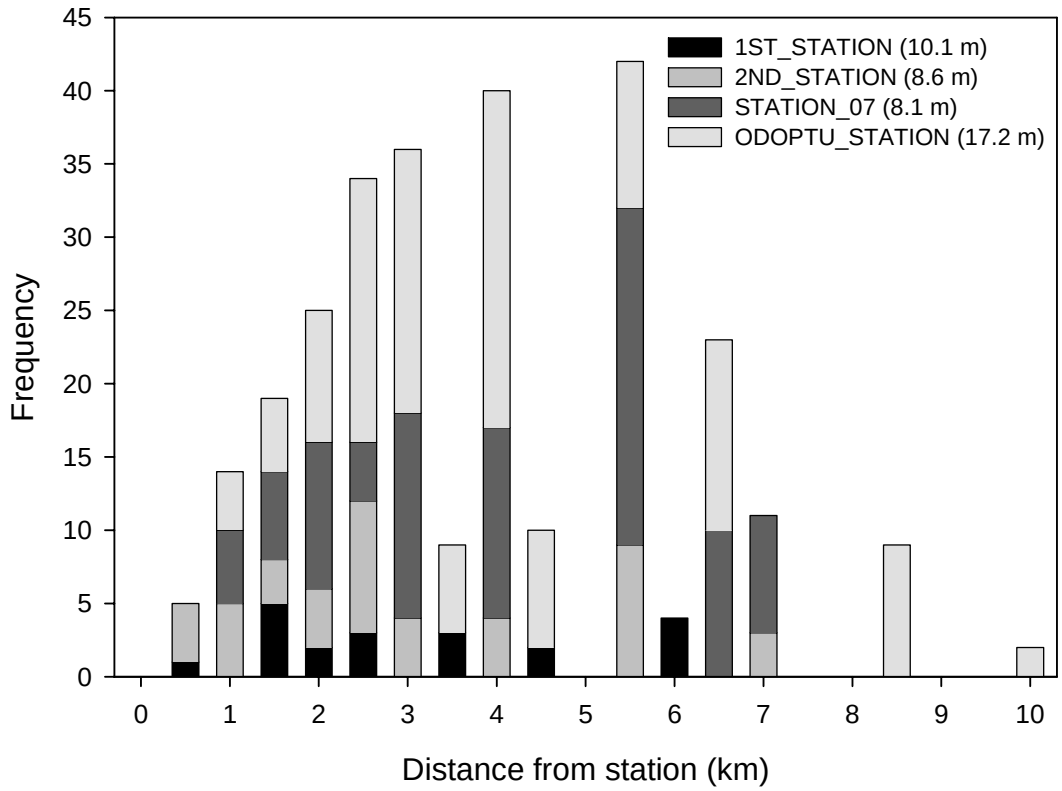


Figure 3. Sighting distances of western gray whales from four shore-based vantage points.

Theodolite Data – Theodolite tracking information was evaluated in terms of each animal's relative speeds, orientations, and displacement. Due to potential issues of oversampling and/or undersampling and to ensure that fixes within a single track were uncorrelated, each trackline was interpolated temporally, as suggested by Turchin (1998). The temporal component was based on evaluating the entire trackline dataset in terms of step lengths, turning angles, number of fixed data points, and fix rate. A 90-sec interpolation criterion was based on an autocorrelation analysis performed on movement patterns (see Würsig et al. 2002). The iterative interpolation strategy started by focusing on the first whale position in a track, and then interpolating a geographic position based on the actual fix data 90-sec apart. After an interpolated position was found, all data between the two positions were discarded to provide even steps for analysis. When completed, interpolation ensured that all locations in a track were equal to the interpolation interval. The result of the interpolation procedure described above yielded tracklines with pairs of fix points (steps) separated by time intervals of approximately 90 seconds.

For each interpolated trackline, the calculated leg speed, acceleration, linearity, reorientation rate, ranging index, and mean vector length were analyzed (see Appendix 1). Leg speed is estimated by calculating the distance traveled between two sequential fixed points within a trackline divided by the time interval between the two points. Acceleration evaluates changes within leg speed to determine if an animal is generally increasing or decreasing speeds within a trackline. Linearity is the deviation of a trackline from that of a straight line and is calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances of each trackline segment along the track. Linearity values range between 0 and 1, where a linearity score close to one represents a straight trackline and a value close to zero represents a track with little or no observed directional movement (Batschelet 1980). In addition to linearity, another directionality index r (mean vector length; Cain 1989) was incorporated due to its dependence on angular change within a trackline as opposed to distances. Mean vector length values range from 0 (great scatter) to 1 (all movements in the same direction) (Cain 1989). Reorientation rates represent a magnitude of bearing changes along a trackline. This rate is calculated as the summation of absolute values of all bearing changes along a trackline divided by the entire duration of the trackline in minutes (Smultea and Würsig 1995).

Two new analyses were conducted in 2003. A ranging index was incorporated that measures the minimal diagonal area of the whale's track incorporating its course and track duration (Jahoda et al. 2003). Furthermore, a "displacement" analysis was conducted to evaluate natural movement patterns among different behavioral states of western gray whales. Displacement is defined as a straight-line distance an animal moved spatially from the start of the track (i.e. step 0) to the nth step. Confidence intervals for the displacement analysis were based on bootstrap methods. The bootstrap was conducted by randomly selecting (with replacement) i_n paths (where i_n was defined as the number of paths that have n moves), and calculating the mean squared displacement. After 1,000 iterations of the bootstrap, the 95% confidence interval for each step were selected from the 26th and 975th values as the lower and upper limits, respectively. Due to the nature of this analysis, all paths were used for low n steps (i.e. step 0), but as n increases the number paths decrease. The consequence of this is greater error bars at higher n steps (Turchin 1998).

Behavioral/Respiration Data – To evaluate potential behavioral changes, focal behavioral data were quantified by six variables: 1) blow interval (time between subsequent exhalations per surfacing); 2) number of blows per surfacing; 3) surface time (time that individuals remain at or near the surface); 4) dive time (time that individuals remain submerged); 5) surface blow rate (mean number of exhalations per minute while the individual is at the surface); and 6) dive-surface blow rate (number of exhalations per minute averaged over the duration of a dive-surface cycle). One approximately 10 min long bin was randomly selected per each behavioral observation session to address independence (autocorrelation), and one mean calculated per each of the six variables per ten minute bin (see next section).

Theodolite and Focal Behavior Data Bins – Due to variation in track duration between tracklines, all tracks were binned into 10-min intervals per tracking/focal follow session. "Binning" involved combining locations within intervals of time lasting approximately 10 min, and viewing the interval of time as the basic observation unit upon which responses and explanatory variables were measured. Each 10-minute interval of time was called a *bin*, and ended at an actual or interpolated location. Due to non-constant track lengths, one or multiple bins were obtained for each track. For each bin, the above-mentioned tracking and behavioral values of interest were calculated. Due to variation in the number of

bins per tracking session, and to avoid pseudoreplication in analyses, one 10-min bin was randomly selected from each trackline or focal behavior session. Therefore, the sampling unit used was one 10-min bin representative per trackline or focal behavior session.

Transformations - Histograms were evaluated for each of the response variables. Transformations for each of non-normal distributions were performed to approximate normal distributions for analysis purposes. The distributions of *linearity* and *mean vector length* were highly skewed, non-normal in shape, and contained values that ranged from 0 to 1. The empirical logit transformation was applied to *linearity* and *mean vector length* using the following equation,

$$Y_i' = \log_e \left[\frac{Y_i - 0.003}{1 - (Y_i - 0.003)} \right],$$

where Y_i' was the transformed response for observation *i*, and Y_i was the original response. The constant 0.003 was subtracted from each observation to avoid division by zero when the original response was 1.0. Back-transformation to the scale of the original response was accomplished using the equation,

$$Y_i = \frac{1.003 \times \exp\{Y_i'\} + 0.003}{1 + \exp\{Y_i'\}}.$$

The distributions of *Leg Speed*, *Reorientation Rate, Blows per Surfacing,* and *Surface Time* were also highly non-normal. Each of these variables were log-transformed using the equation,

$$Y_i' = \log_e(Y_i).$$

Again, Y_i' was the transformed response for observation *i*, and Y_i was the original response. Back-transformation to the scale of the original response was accomplished by raising *e* to the Y_i' power.

RESULTS

Effort

The 2003 field season commenced on 18 July 2003 and ended on 14 September 2003. Due to poor weather conditions consisting of fog, rain, and storms, July was represented by only one full-day of effort (22 July), conducted at Odoptu Station. Early August consisted of many days with little to no visibility and high sea state. The first full-day of data collection after 22 July started on 13 August at 1st Station. The last field day of effort was 13 September at Station 07. Thirty days (233 hrs) of effort were spent at the four shore-based stations (Table 2, Appendix 3).

Table 2. Total amount of effort at four shore-based stations during 18 July to 14 September, 2003.

Station	Days	Scans	Effort (hrs)
1st_Station	8	46	55.02
2nd_Station	8	37	50.39
Station_07	9	55	76.39
Odoptu_Station	5	29	51.11
Total	30	167	232.91

Scan Data

General – A total of 167 scans with 410 whales from 313 sightings were accumulated for the duration of the study, with a mean of 4.0 ± 2.41 SD scans conducted per day of effort. Distribution of sightings from the four stations is shown in Figure 4; this demonstrates graphically that although whales could be sighted up to about 10 km distance from the station with the highest elevation (Odoptu Station, 17.2 m), they were rarely > 4 km from shore (Fig. 5, Table 3, see Appendix 4 for daily scan plots).

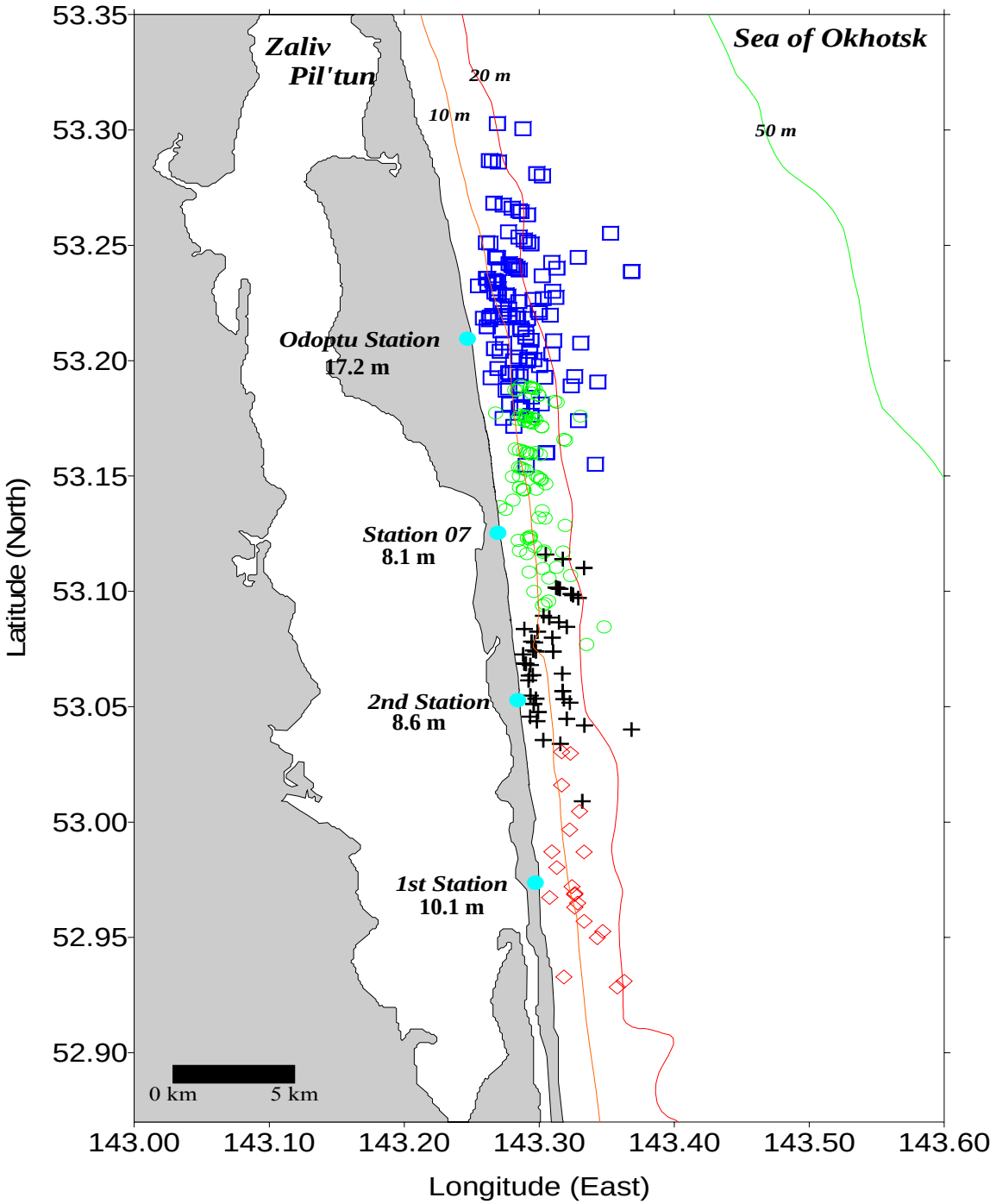


Figure 4. Geographic positions of sightings of western gray whales at four shore-based stations on Sakhalin Island, summer 2003.

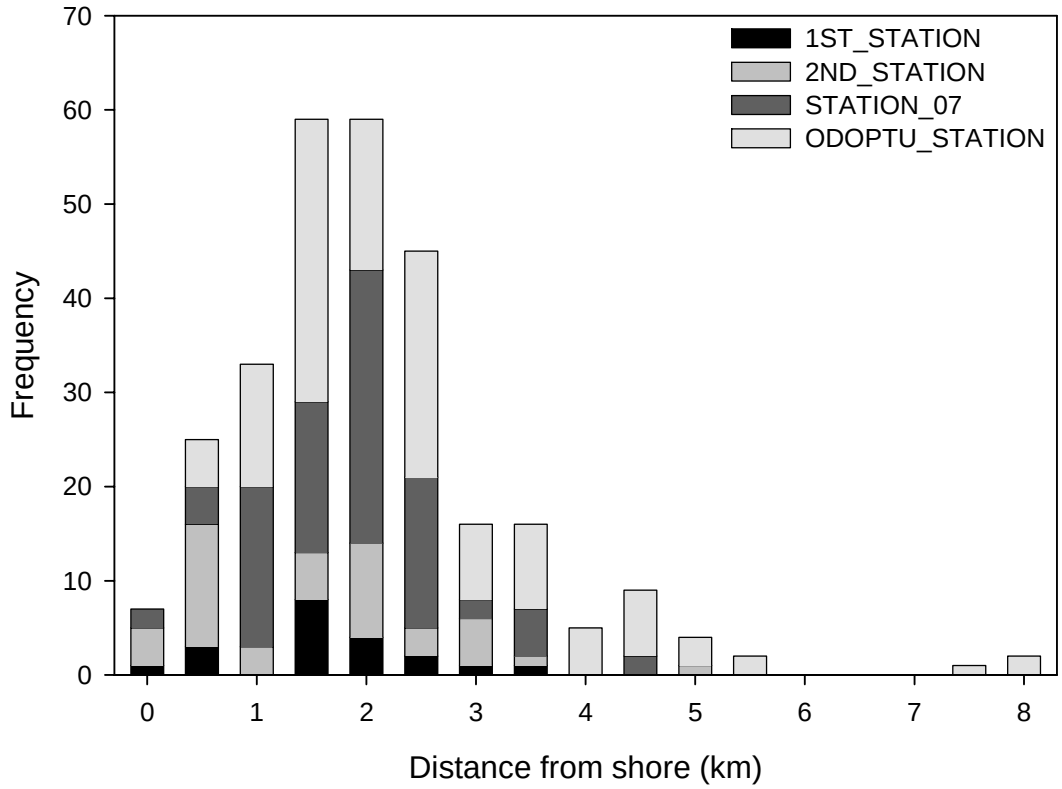


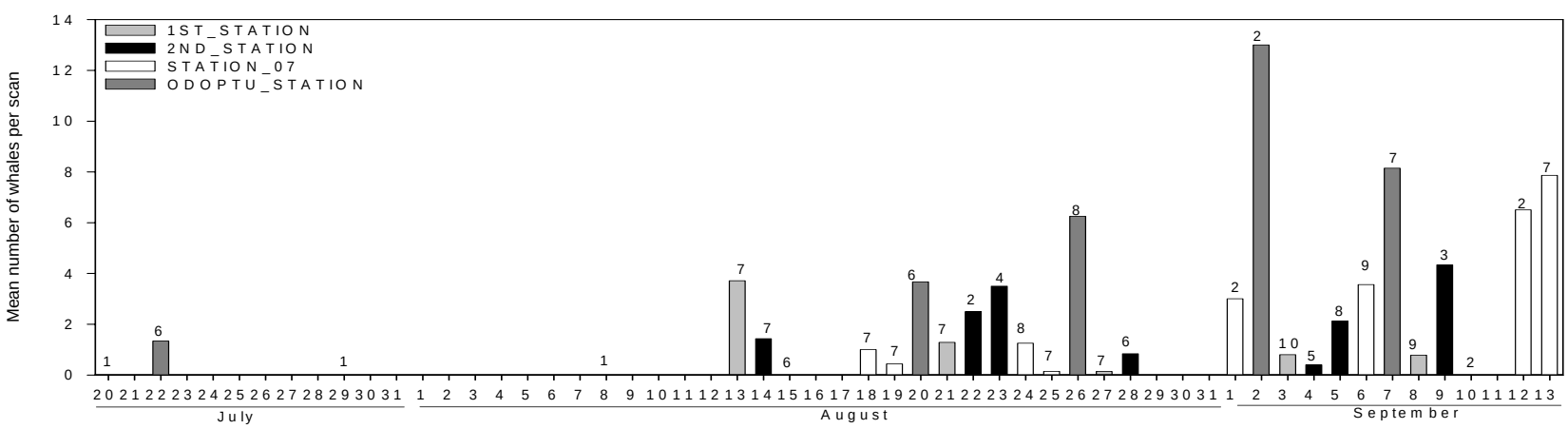
Figure 5. Distance of western gray whale sightings from shore off Sakhalin Island, summer 2003.

Table 3. Distance of western gray whales from shore at four shore-based stations. Sample size represents number of sighting (30 sightings were removed from this analysis due to missing parameters related to distance estimation).

Stations	Mean (km)	Median (km)	SD (km)	N
1st_Station	1.9	1.8	0.81	20
2nd_Station	1.8	1.9	1.13	45
Station_07	2.1	2.0	0.81	93
Odoptu_Station	2.7	2.5	1.44	125
Total	2.3	2.1	1.23	283

Gray whales were mostly present on each day of effort, with a mean of 2.0 ± 2.62 SD (Median = 1, Range: 0-15, N = 167) whales and 1.6 ±1.95 (1, 0-8, 167) pods in the study area per scan. The mean pod size detected was 1.3 ±0.56 (1, 1-4, 313) whales per pod throughout the duration of this study (Figs. 6 and 7).

A.



B.

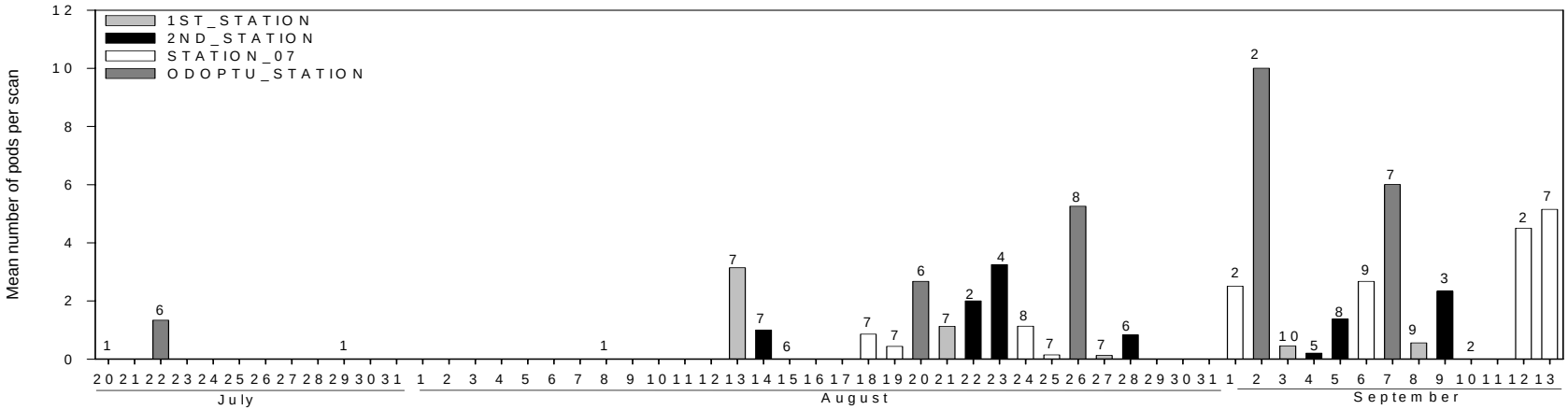
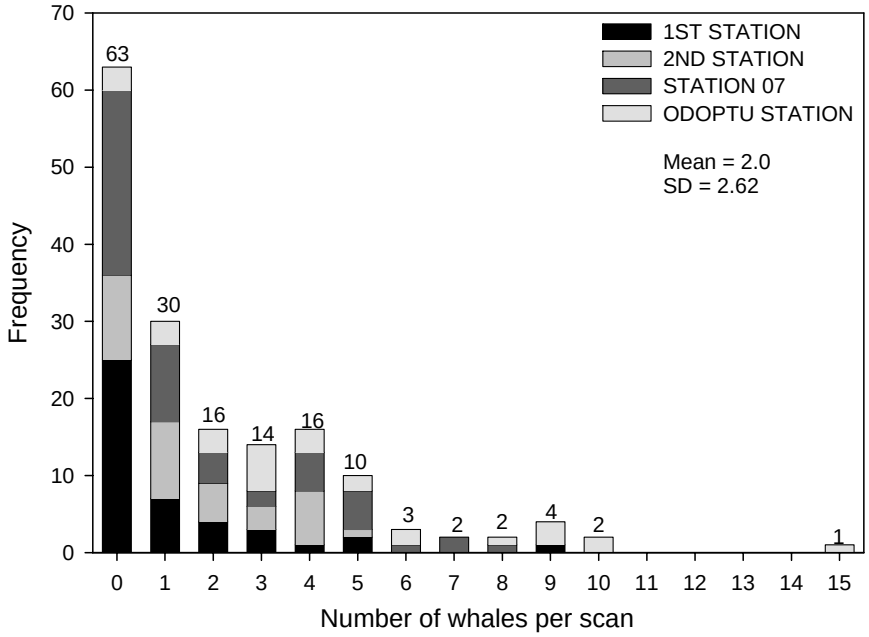


Figure 6. Mean numbers of whales (A) and pods (B) detected per scan at each of the four shore-based stations. The number of scans performed per day at each station is indicated at the top of each bar.

A.



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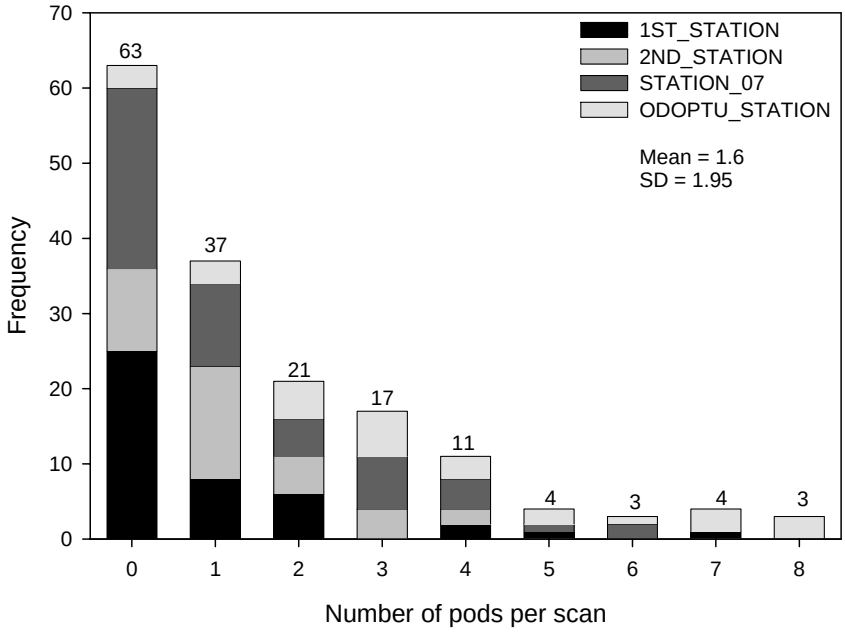

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C.

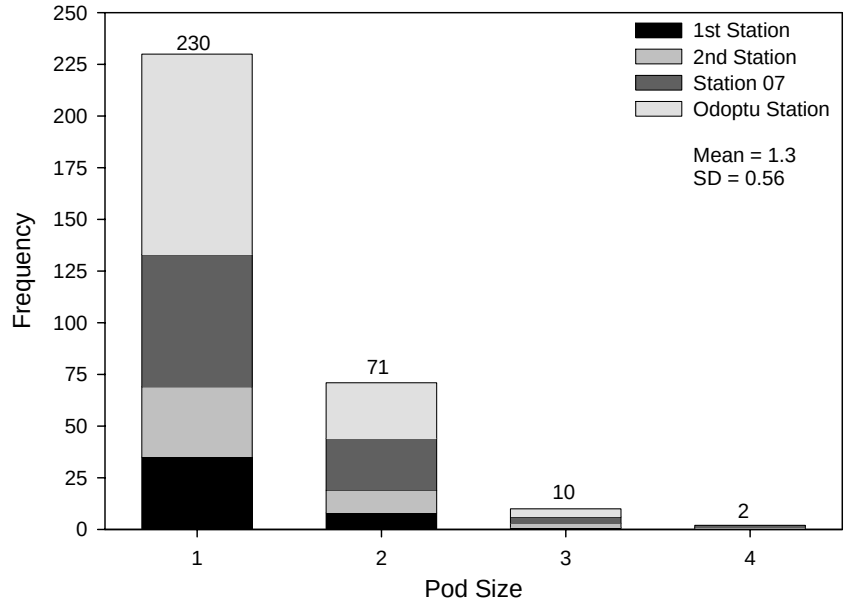
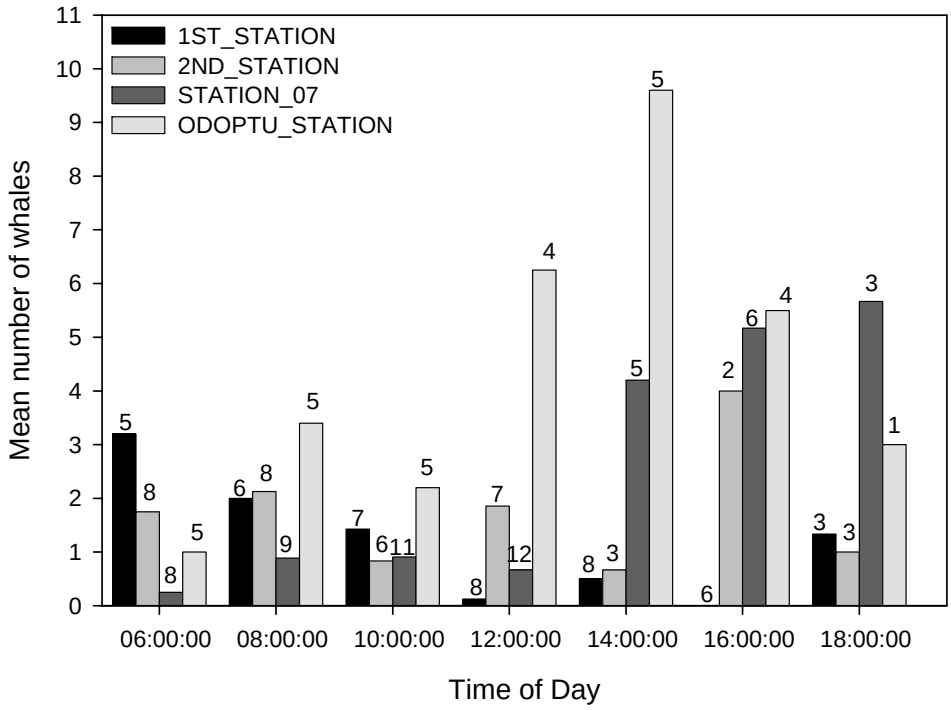


Figure 7. Frequency histograms of numbers of whales (A) and pods (B) detected per scan throughout the study period, and pod size (C). A Number of whales and pods were removed from this analysis due to differences in station heights (see methods).

<u>Morning vs Afternoon</u> - No significant difference in the number of whales (Z = -1.32, P = 0.174) or pods (-1.45, 0.147) were detected in the morning and afternoon periods of each day (Fig. 8). In the morning, the mean number of whales was 2.3 ± 3.33 SD (Median = 1, Range: 0-17, N = 89); and in the afternoon, the mean number of whales was 2.7 ± 3.18 (1, 0-12, 78). In the morning, the mean number of pods was 1.7 ± 2.36 (1, 0-11, 89); and in the afternoon, the mean number of pods was 2.1 ± 2.33 (1, 0-9, 89).

A.



B.

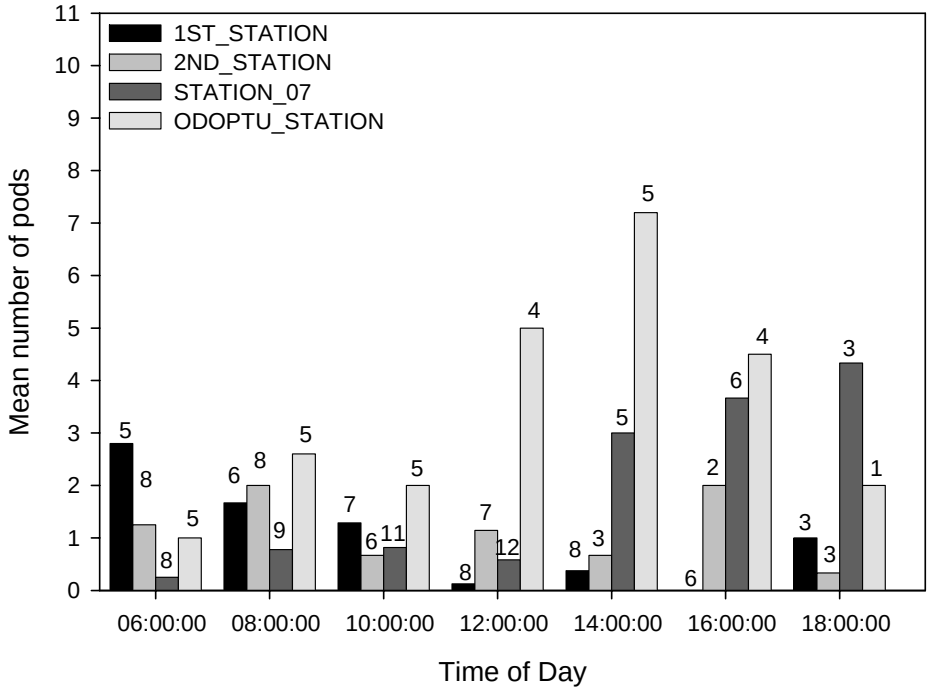


Figure 8. Mean number of whales (A) and pods (B) per time of day at four shore-based stations.

Stations – The mean numbers of whales and pods observed for the season among stations were significantly different (whales F = 15.14, df = 3, P < 0.001; pods 19.32, 3, <0.001), with more whales and pods at the northern-most shore-based station (Odoptu Station, $\bar{\chi}$ =5.6 ± 4.31 SD whales and 4.4 ± 3.01 pods) on average for the season, compared to the other three stations (see Fig. 6 and Table 4). Although the Odoptu station was the highest vantage point among the four stations, this difference in number of whales and pods is unlikely to be affected by elevation differences since we removed sightings beyond the critical 6 km distances, where all stations have similar probabilities of detecting whales up to that distance from the observer (see methods). The numbers of whales and pods were found to be similar at the other three shore-based stations (1.2 ± 1.84 to 2.3 ± 3.32 whales and 1.0 ± 1.50 to 1.7 ± 2.22 pods), with 1st station having the lowest number of whales and pods per scan. This same geographic pattern of relative abundance was observed in 2002 at the same shore-based stations (Würsig et al., 2003).

Table 4. Number of whales (A) and pods (B) detected at four shore-based stations. Samples size is represented by the number of scans per station.

A.

Station	Mean	SD	Median	Range	N
1st_Station	1.2	1.84	0	0-9	46
2nd_Station	1.8	1.75	1	0-6	37
Station_07	2.3	3.32	1	0-12	55
Odoptu_Station	5.6	4.31	5	0-17	29

B.

Station	Mean	SD	Median	Range	N
1st_Station	1.0	1.50	0	0-7	46
2nd_Station	1.3	1.22	1	0-4	37
Station_07	1.7	2.22	1	0-7	55
Odoptu_Station	4.4	3.01	4	0-11	29

Theodolite Tracklines

Gray whales were tracked for at total of 57 hours ($\overline{\chi}$ = 47.0 min./track), ranging from 5 min to 3.42 h of continuous monitoring of movement patterns (Table 5). We recorded a total of 73 different tracklines with 4,309 geographic positions (Fig. 9).

Table 5. Summary of trackline data gathered at four shore-based stations.

Station	# Tracklines	Avg Duration (min.)	Range (min.)
1st Station	14	41.7	6 - 127
2nd Station	20	43.1	7 - 155
Station 07	12	61.9	7 - 205
Odoptu Station	27	46.1	5 - 189
Total	73	47	5 - 205

The analytical data set, consisting of only recognizable or single individuals, yielded 47 tracklines that could be used for analysis (Table 6). On average, gray whales observed during the duration of the study were moving 2.3 ± 1.04 SD kph (Median = 2.1, Range = 0.4-4.4; Fig. 10), accelerating -0.04 ± 0.229 kph (-0.03,-0.87– 0.68; Fig. 11), reorienting 26.0 ± 18.76 °/min (20.9, 1.5 – 72.9; Fig. 12), and ranging 31.1 ± 18.06 m/min (30.3, 4.8 – 69.9; Fig. 15). The mean vector length and linearity index were 0.69 ± 0.293 (0.79, 0.05 – 1.00; Fig. 13) and 0.75 ± 0.286 (0.89, 0.03 – 1.00; Fig. 14), respectively. These directional indices indicate a more straight-line path movement as opposed to a non-directional feeding type behavior.

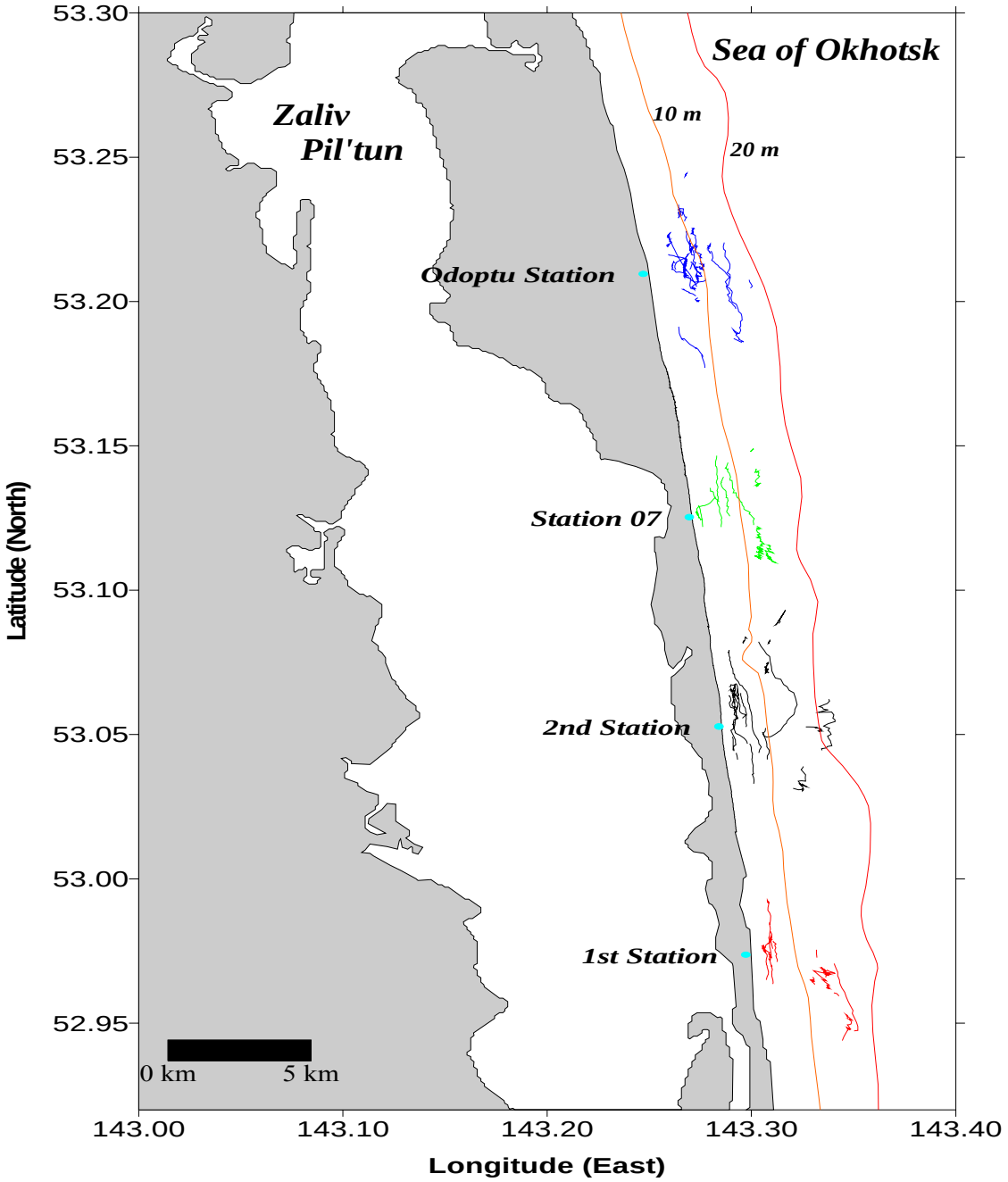


Figure 9. Tracklines of western gray whales at four shore-based positions on Sakhalin Island during summer 2003 (N = 73).

Table 6. Summary data for trackline analysis of western gray whales during summer 2003.

N = 47 tracklines	Mean	Median	Min	Max	SD
Leg Speed (kph)	2.3	2.1	0.4	4.4	1.04
Reorientation Rate (°/min.)	26.0	20.9	1.5	72.9	18.76
Acceleration (kph)	-0.04	-0.03	-0.87	0.68	0.229
Mean Vector Length	0.69	0.79	0.05	1.00	0.293
Linearity Index	0.75	0.89	0.03	1.00	0.286
Ranging Index (m/min.)	31.1	30.3	4.8	69.9	18.06

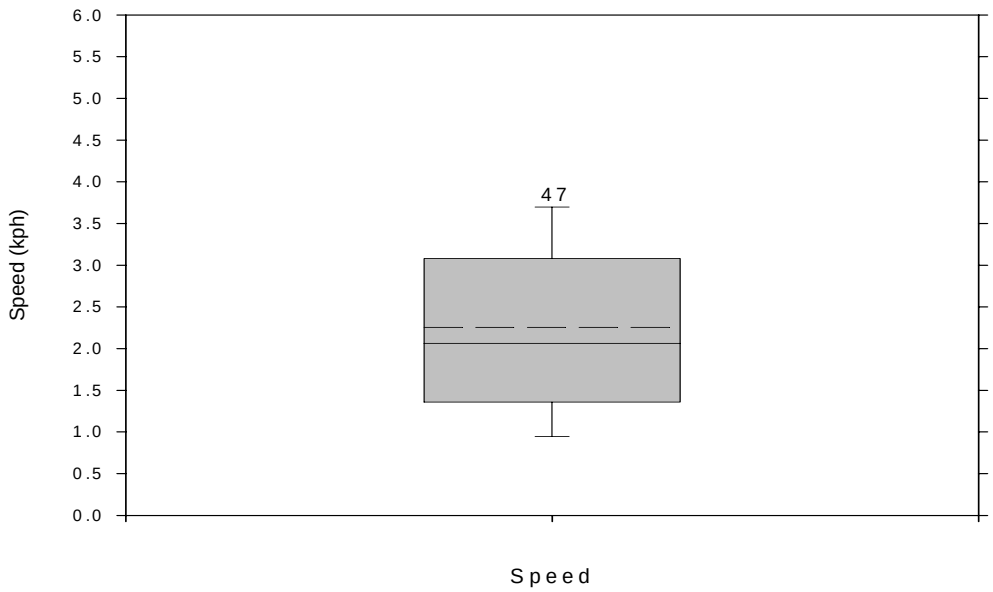


Figure 10. Leg Speed for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

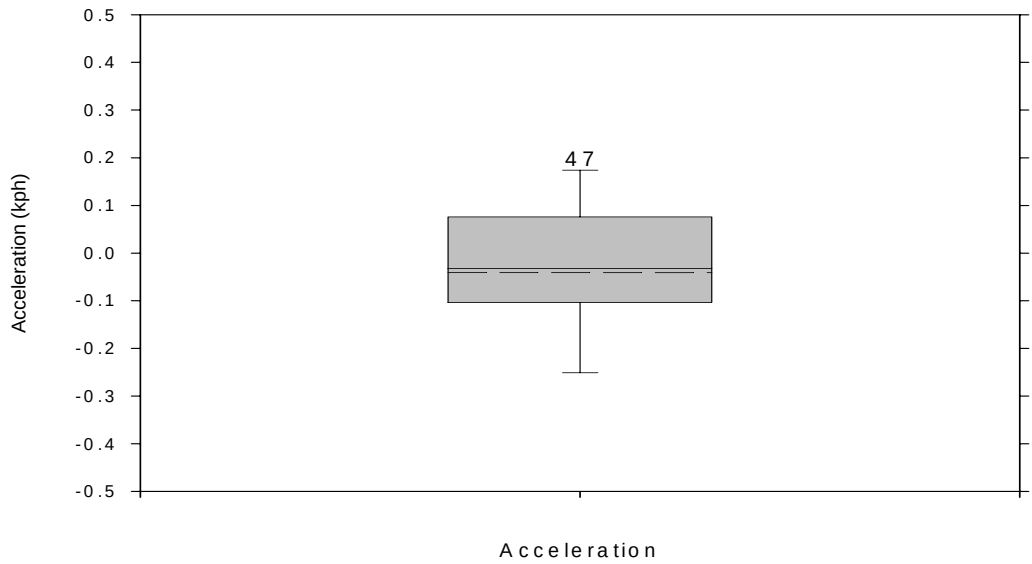


Figure 11. Acceleration for all single or recognizable individual gray whales observed at four shore-based stations. The negative values of acceleration represent deceleration. For each box-plot, the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

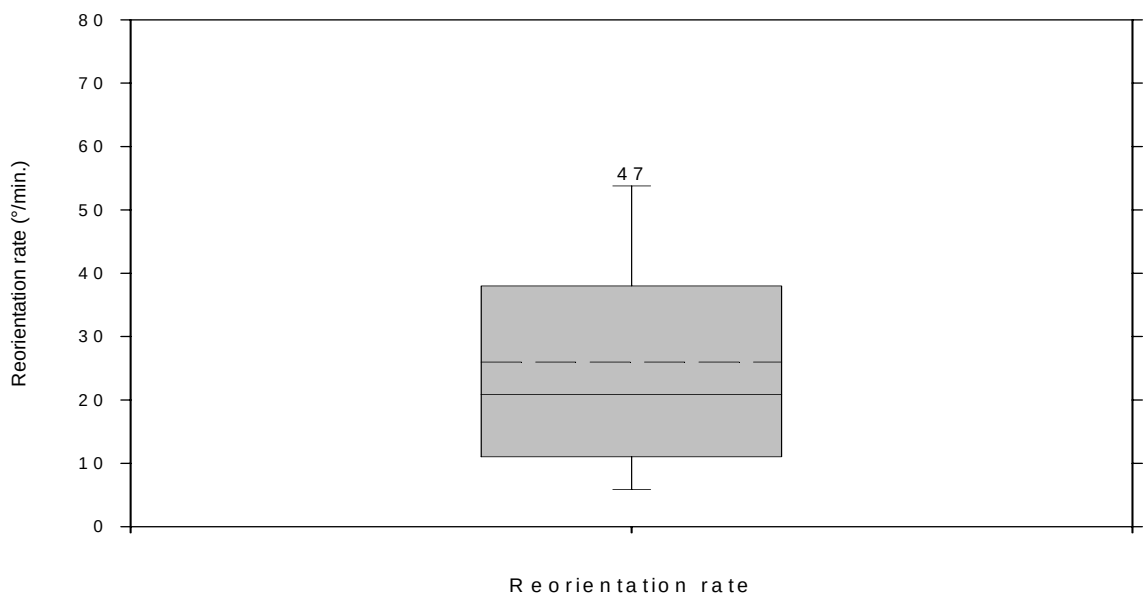


Figure 12. Reorientation rate for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

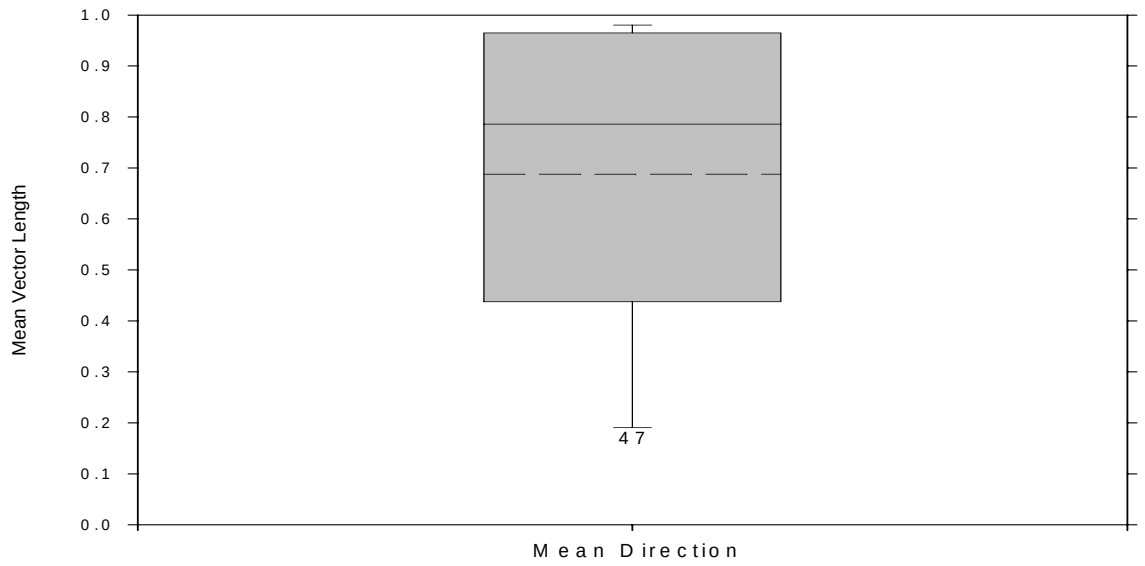


Figure 13. Mean vector length for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

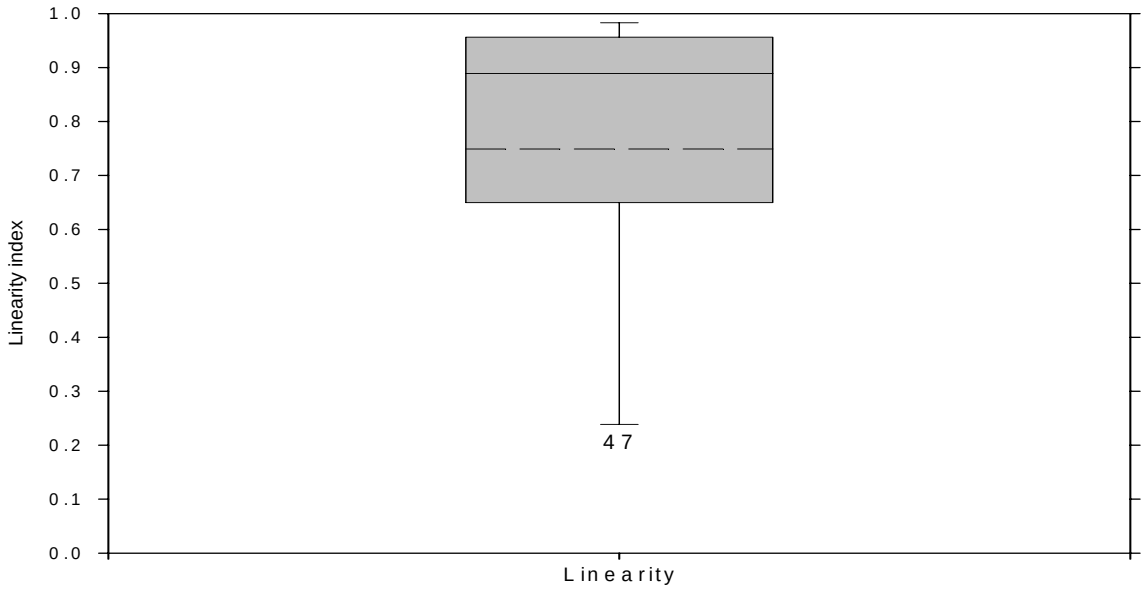


Figure 14. Linearity index for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

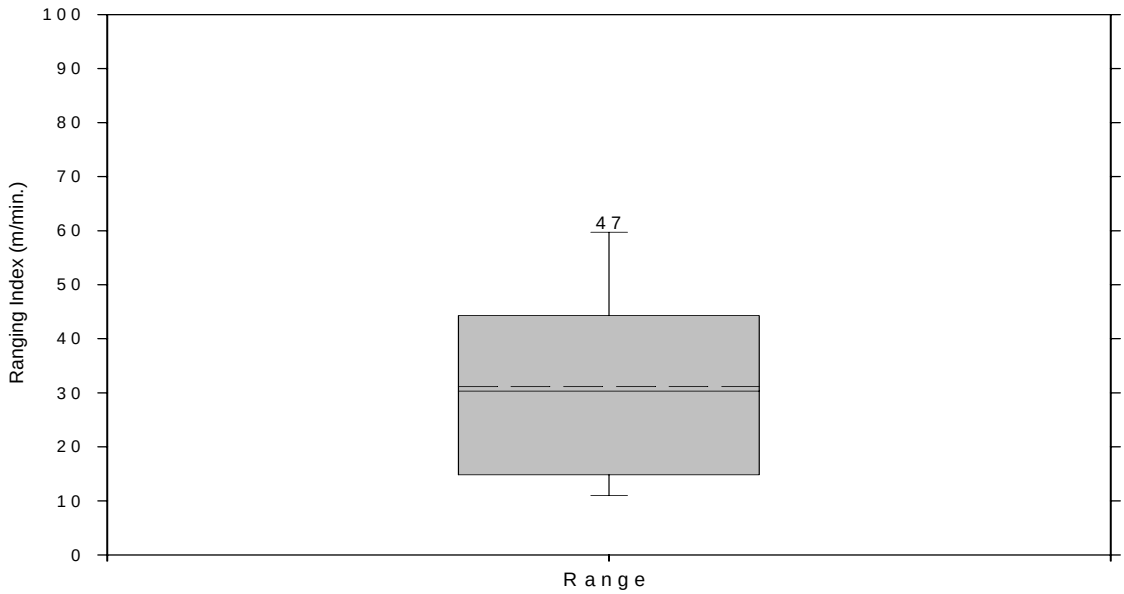


Figure 15. Ranging index for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

Focal Behavior Observations

Focal behavioral observations were conducted for a total of 35 h, on 36 individual gray whales from 29 July to 13 September 2003 (Table 7). The mean duration of a focal session lasted approximately 58 min, and a total of 2,089 behavior events were collected.

Table 7. Summary of focal behavior data gathered at four shore-based stations.

Station Name	# Focals	Mean Duration (min)	Range (min)
1st Station	7	42.3	21 - 108
2nd Station	6	50.1	16 - 98
Station 07	11	53.7	10 - 187
Odoptu Station	12	75.1	10 - 187
Total	36	58.0	10 - 187

On average, individual gray whales had a blow interval of 0.37 ± 0.133 SD blows per minute (Median = 0.35, Range = 0.18 – 0.67; Fig. 16), with 4.18 ± 1.380 (4.00, 2 – 7; Fig. 17) blows per surfacing. The time that individuals were observed at the surface was 1.68 ±

1.783 (1.17, 0.28 – 7.00; Fig. 16) minutes, while individuals dove for 2.17 ± 0.767 (2.08, 1.05 – 4.10; Fig. 16) minutes. The dive surface blow rate and surface blow rate were 1.29 ± 0.418 (1.20, 0.72 – 2.54, Fig. 17) blows per minute and 4.35 ± 0.317 (4.00, 2.00 – 4.50, Fig. 17) blows per minute, respectively (Table 8).

Table 8. Summary statistics for surface-respiration-dive parameters of individual western gray whales.

N = 34	Mean	Median	Min	Max	SD
Blow Interval (per min.)	0.37	0.35	0.18	0.67	0.133
Blows/Surfacing	4.18	4.00	2.00	7.00	1.380
Surface Time (min.)	1.68	1.17	0.28	7.00	1.783
Dive Time (min.)	2.17	2.08	1.05	4.10	0.767
Surface Blow Rate	4.35	4.00	2.00	4.50	1.840
Dive-Surface Blow Rate	1.29	1.20	0.72	2.54	0.418

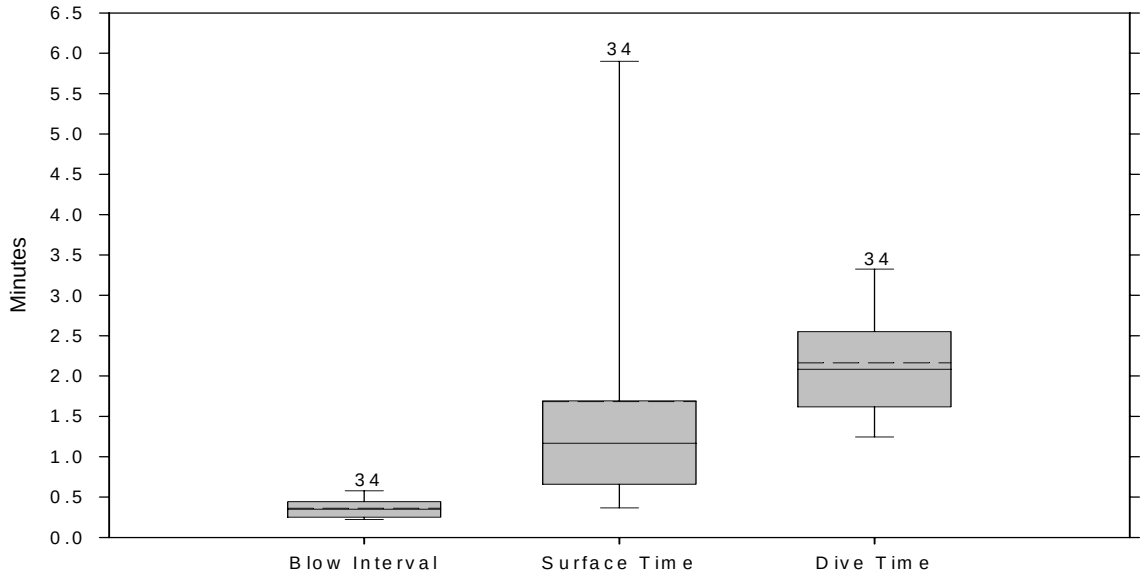


Figure 16. Blow interval, surface time, and dive time parameters of western gray whales. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

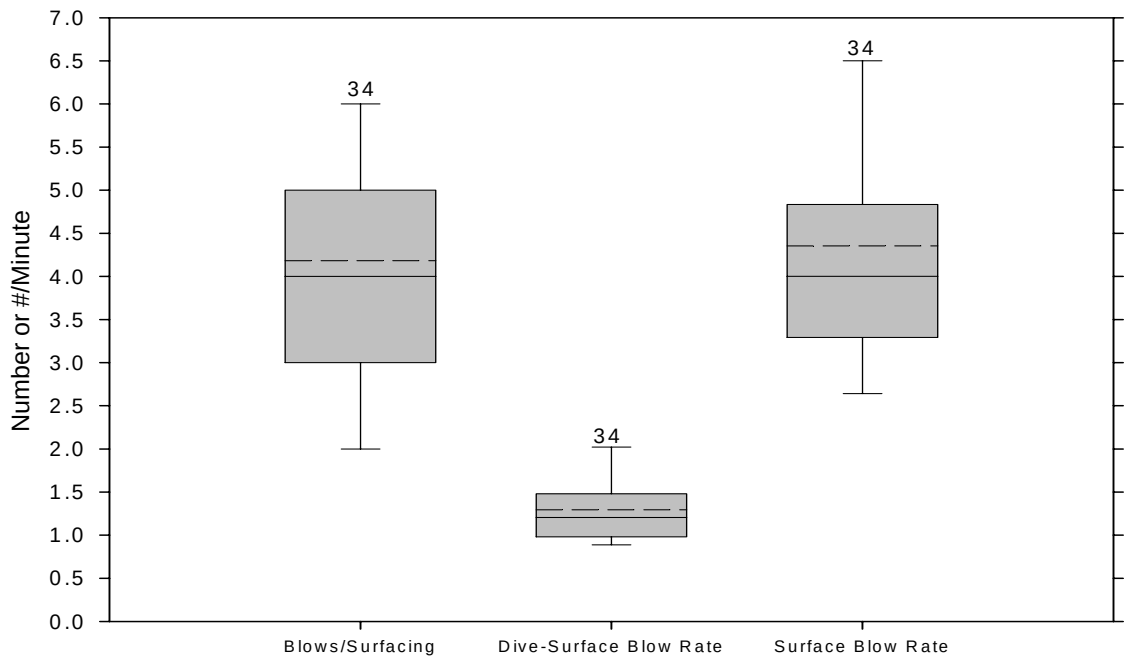


Figure 17. Number of blows per surfacing, dive-surface blow rate, and surface blow rate of western gray whales. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

Behavior

Three main behavioral states were observed during the 2003 field season: 1) Feeding – whale(s) generally remain in one localized area with non-directional movement and consistent periods of diving; 2) Feeding/Traveling – whale(s) swim in one general direction at relatively slow speeds with consistent periods of diving; and 3) Traveling – whale(s) swim in one general direction and often remain at the surface without consistent dives. Although other behavioral states were observed, such as milling, socializing, and resting, there are too few occurrences of these behavioral states to provide a detailed analysis.

The gray whales' speeds (F = 10.73, df = 2, P = <0.01), reorientation rates (18.00, 2, <0.01) and ranging indices (16.13, 2, <0.01) were significantly different among the three behaviors. Linearity (15.44, 2, <0.01) and mean vector length (21.10, 2, <0.01) were significantly different between feeding versus feeding/traveling versus feeding and traveling. Feeding/traveling and traveling were not significantly different for linearity and mean vector length. The respiration interval (6.11, 2, <0.01) and dive-surface blow rate (3.53, 2, 0.04) were different between feeding and traveling and feeding/traveling and traveling, respectively. Acceleration, distance to shore, surface time, dive time, and surface blow rate

were all non-significant among the three behavioral states (Table 9, Figs. 18 - 29). The "displacement" of whales among the three behavioral states also revealed significant differences with individuals displacing 0.01 km^2 (95% Confidence interval: 0.05 – 0.16 km^2), 0.74 km^2 (0.41 - 1.17 km^2), and 1.27 km^2 (0.85 – 1.56 km^2) during feeding, feeding/traveling, and traveling behavioral states, respectively, after 20 steps (i.e. 30 minutes) (Fig. 30).

Table 9. Movement and respiration variables of western gray whales during feeding, feeding/traveling, and traveling behavioral states. Post-hoc significance is denoted by F (Feeding), FT (Feeding/Traveling), and T (Traveling).

Variable	Feeding	Feeding/Traveling	Traveling	F	P	Post-hoc Significance
Speed (kph)	1.6 ± 0.75 (20)	2.6 ± 1.56 (22)	3.6 ± 1.26 (15)	10.73	<0.01	F-T, FT-T, FT-F
Reorientation rate	38.7 ± 14.98 (20)	23.0 ± 18.52 (22)	10.5 ± 5.94 (15)	18.00	<0.01	F-T, FT-T, FT-F
Linearity Index	0.54 ± 0.271 (20)	0.78 ± 0.274 (22)	0.94 ± 0.067 (15)	15.44	<0.01	F-T, FT-F
Mean vector length	0.46 ± 0.229 (20)	0.77 ± 0.240 (22)	0.92 ± 0.078 (15)	21.10	<0.01	F-T, FT-F
Acceleration (kph)	0.15 ± 0.388 (20)	-0.0 ± 0.423 (22)	0.13 ± 0.296 (15)	1.23	0.30	
Ranging index (m/min)	17.0 ± 7.617 (20)	37.1 ± 26.97 (22)	57.1 ± 22.01 (15)	16.13	<0.01	F-T, FT-T, FT-F
Distance to shore	1.46 ± 0.707 (20)	1.25 ± 0.882 (22)	1.10 ± 0.832 (15)	0.84	0.44	
Respiration Interval	0.32 ± 0.118 (16)	0.42 ± 0.162 (13)	0.52 ± 0.135 (8)	6.11	0.01	F-T
Surface Time (min)	0.94 ± 0.657 (16)	1.97 ± 1.992 (13)	3.58 ± 3.606 (8)	3.25	0.05	
Dive Time (min)	2.19 ± 0.491 (16)	2.36 ± 0.923 (13)	1.67 ± 0.637 (8)	1.93	0.16	
Dive-surface blow rate	1.25 ± 0.361 (16)	1.17 ± 0.296 (13)	1.68 ± 0.518 (8)	3.53	0.04	FT-T
Surface blow rate	3.70 ± 1.418 (16)	5.75 ± 3.158 (13)	13.9 ± 20.70 (8)	3.01	0.07	

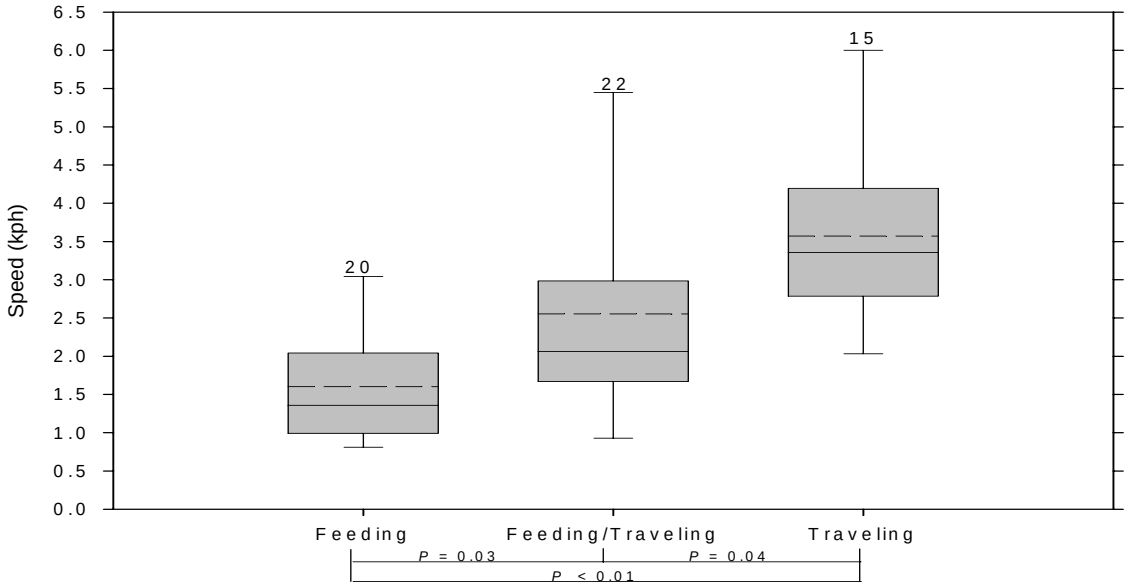


Figure 18. Speed of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

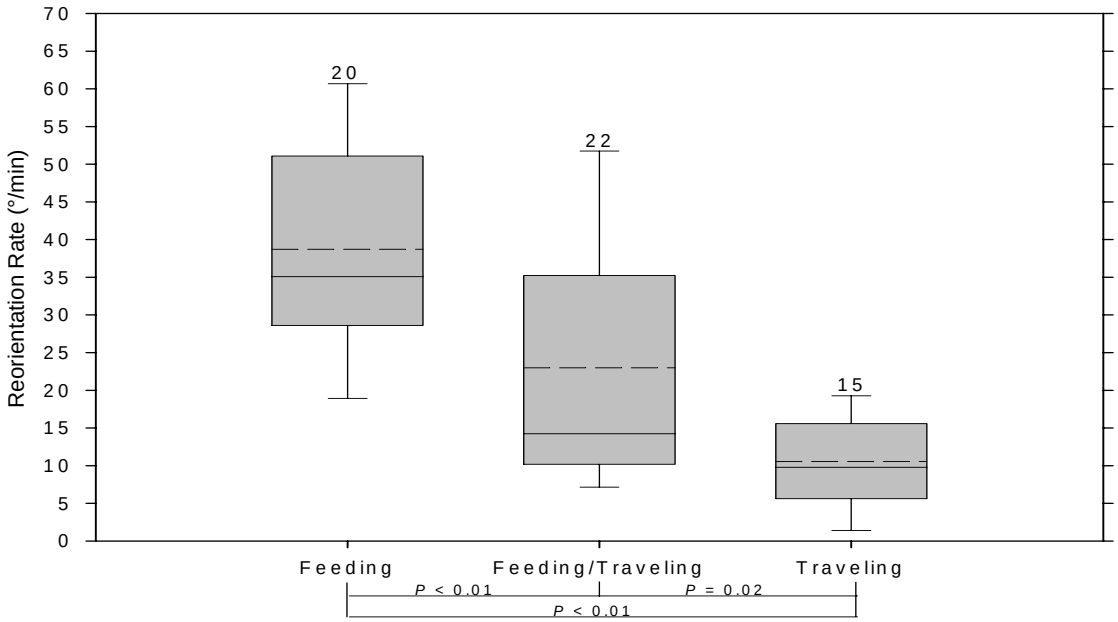


Figure 19. Reorientation rate of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

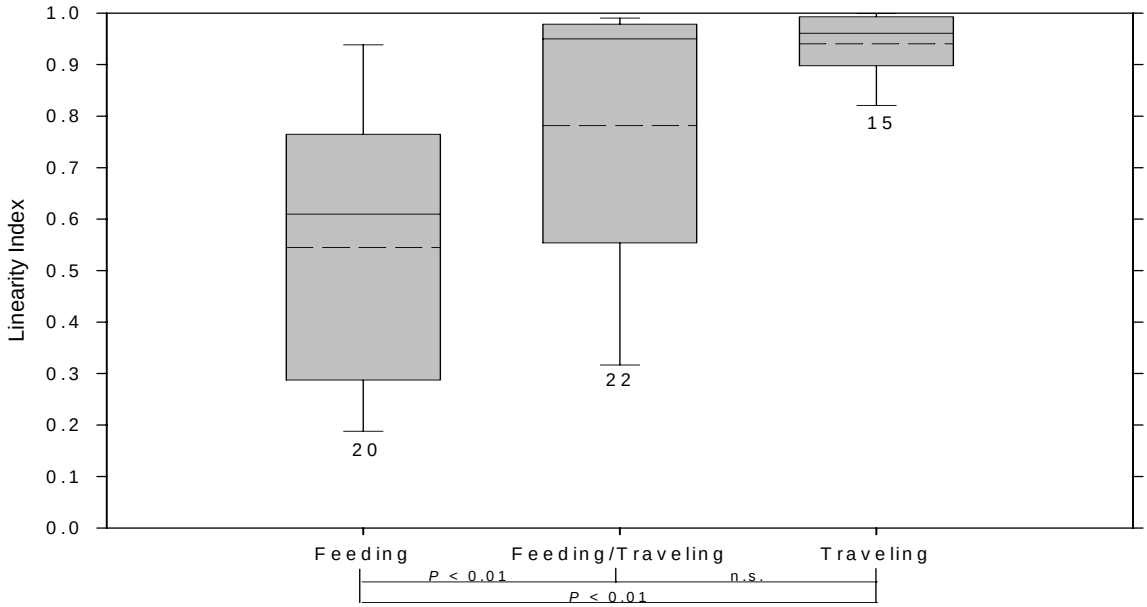


Figure 20. Linearity index of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

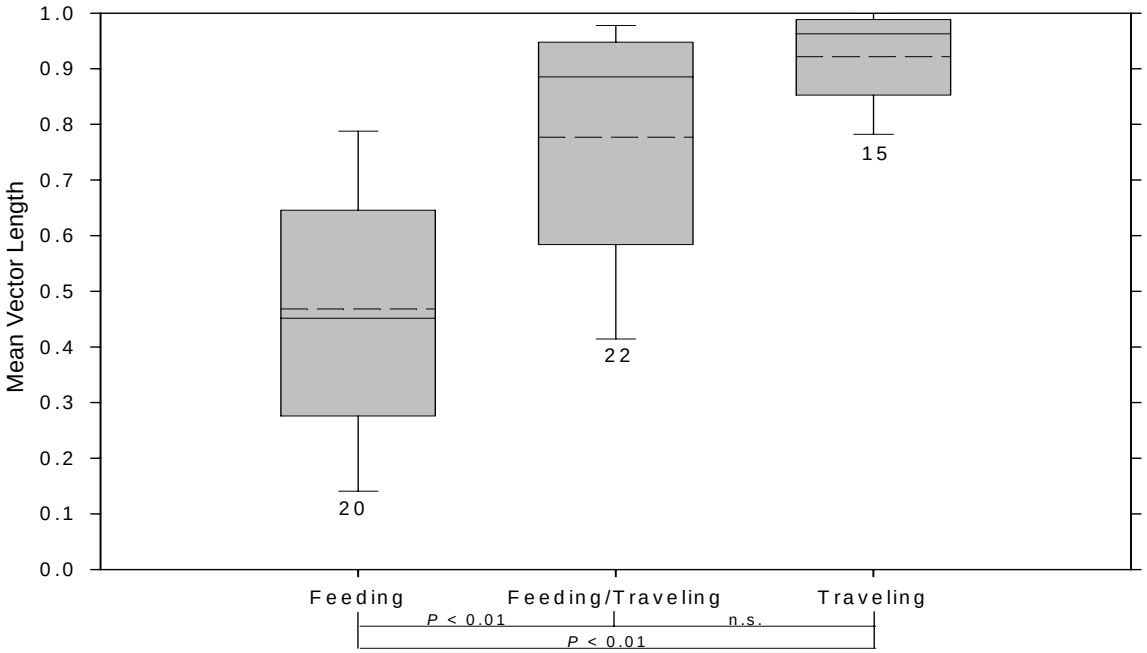


Figure 21. Mean vector length of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

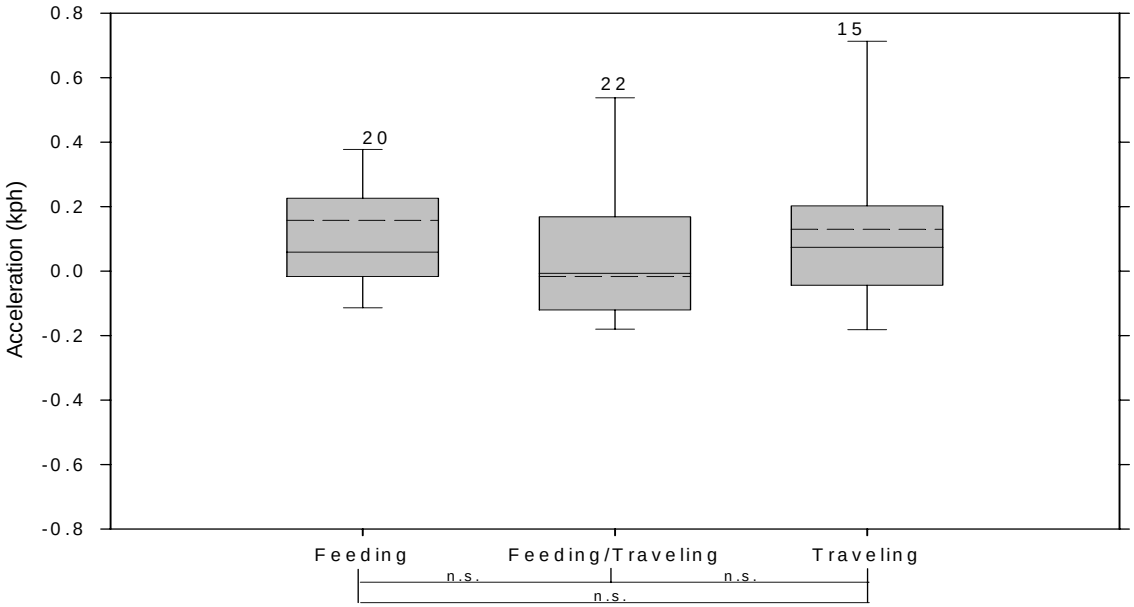


Figure 22. Acceleration of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

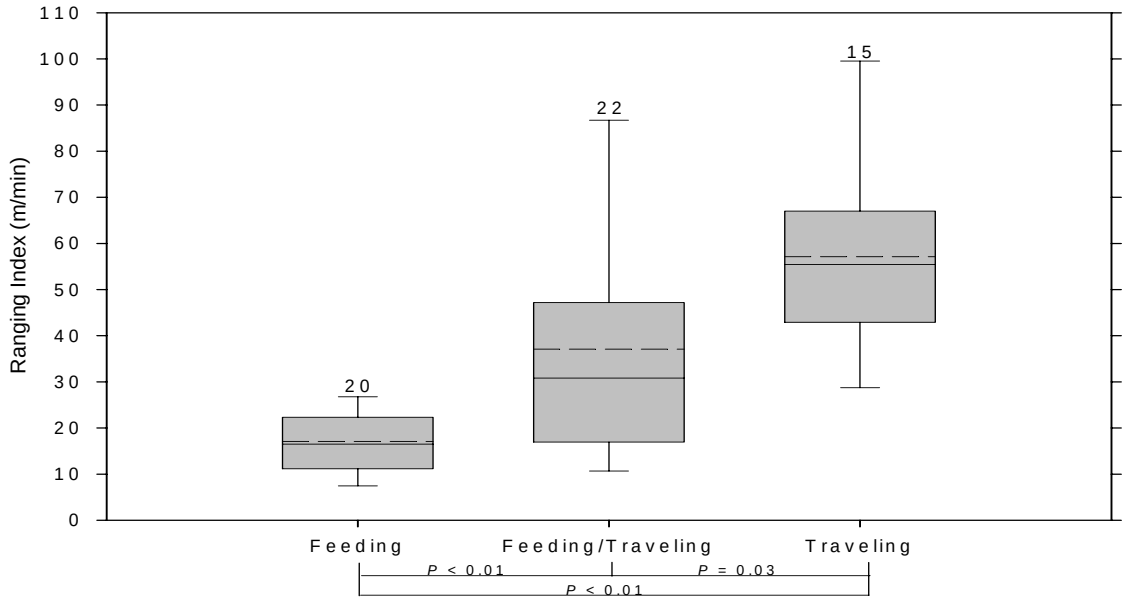


Figure 23. Ranging index of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

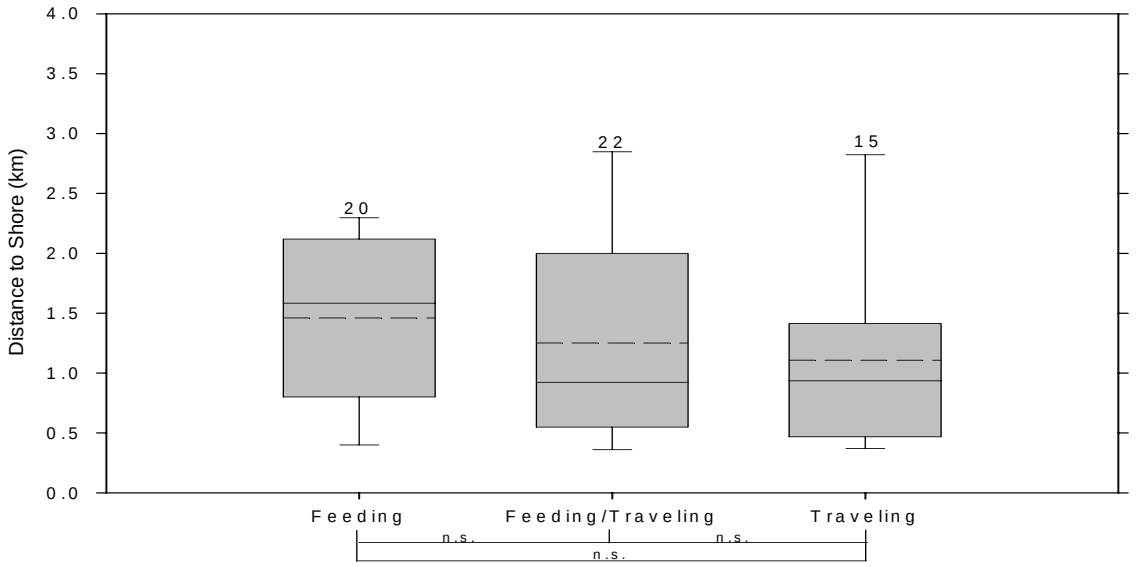


Figure 24. Distance to shore of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

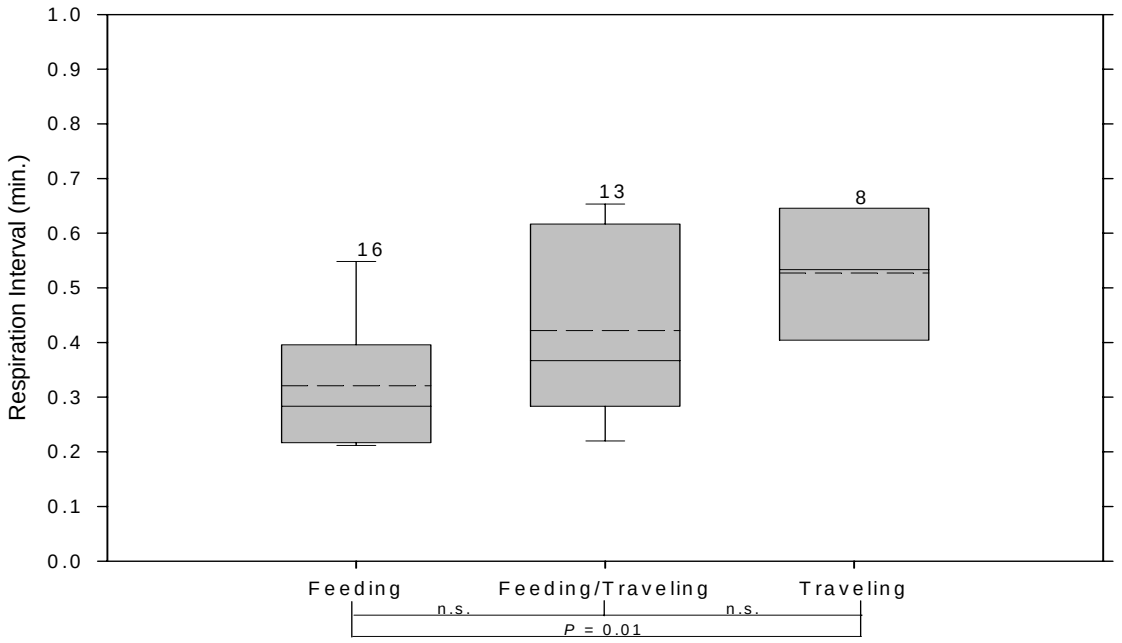


Figure 25. Respiration interval of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

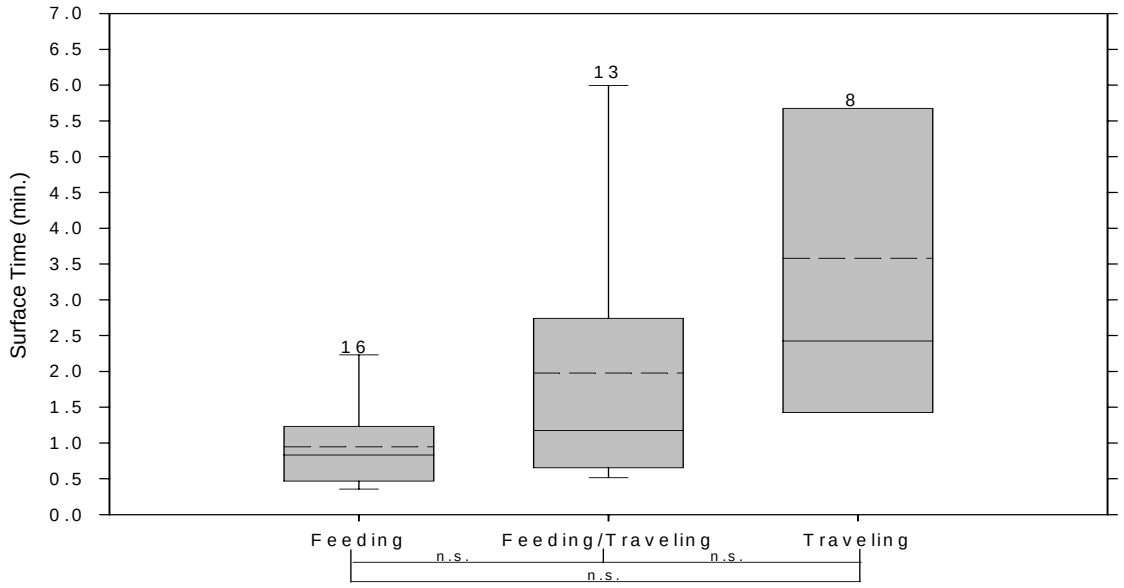


Figure 26. Surface time of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

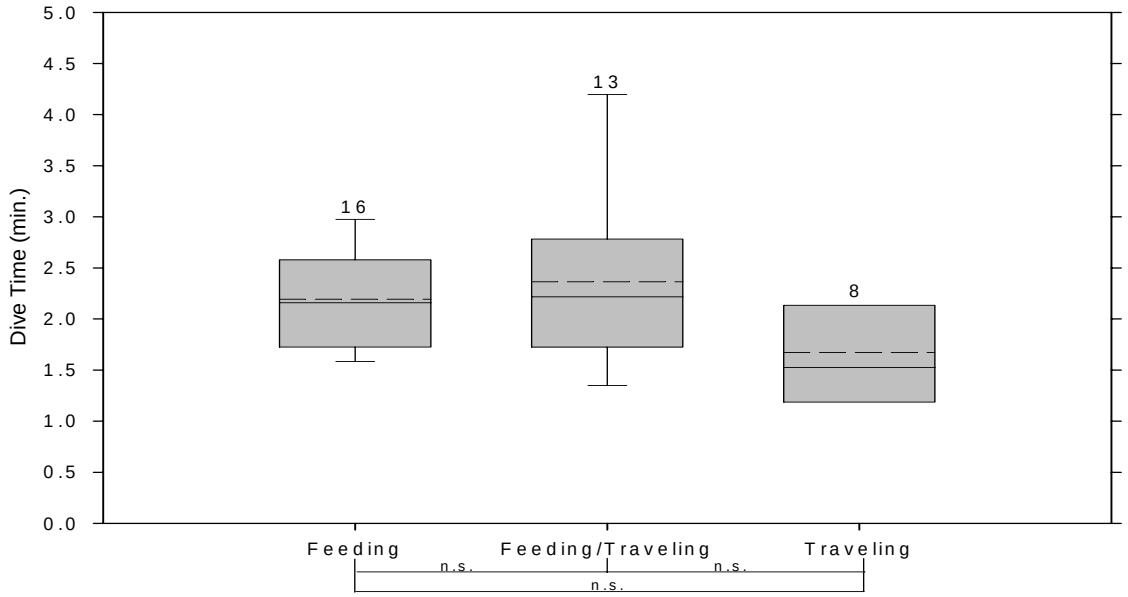


Figure 27. Dive time of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

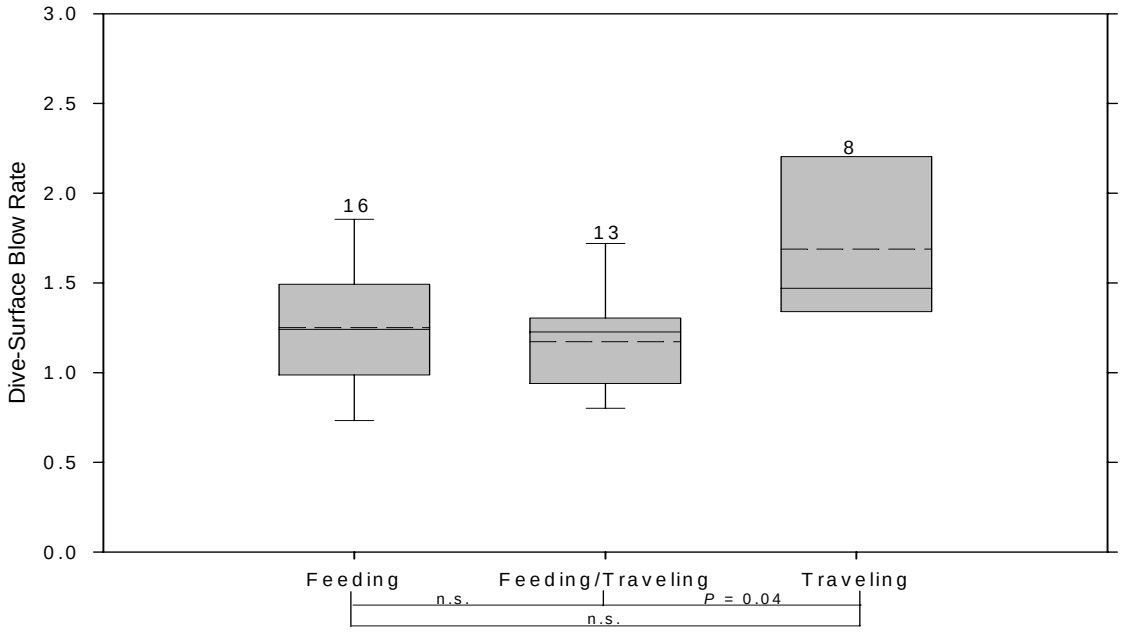


Figure 28. Dive-surface blow rate of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

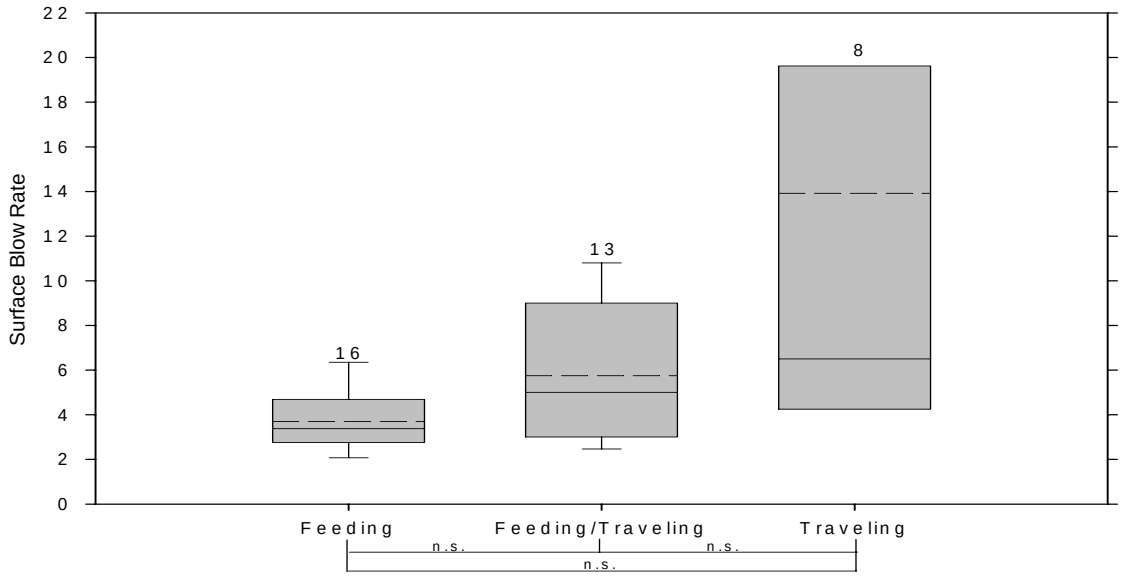


Figure 29. Surface blow rate of western gray whales during three behavioral states. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

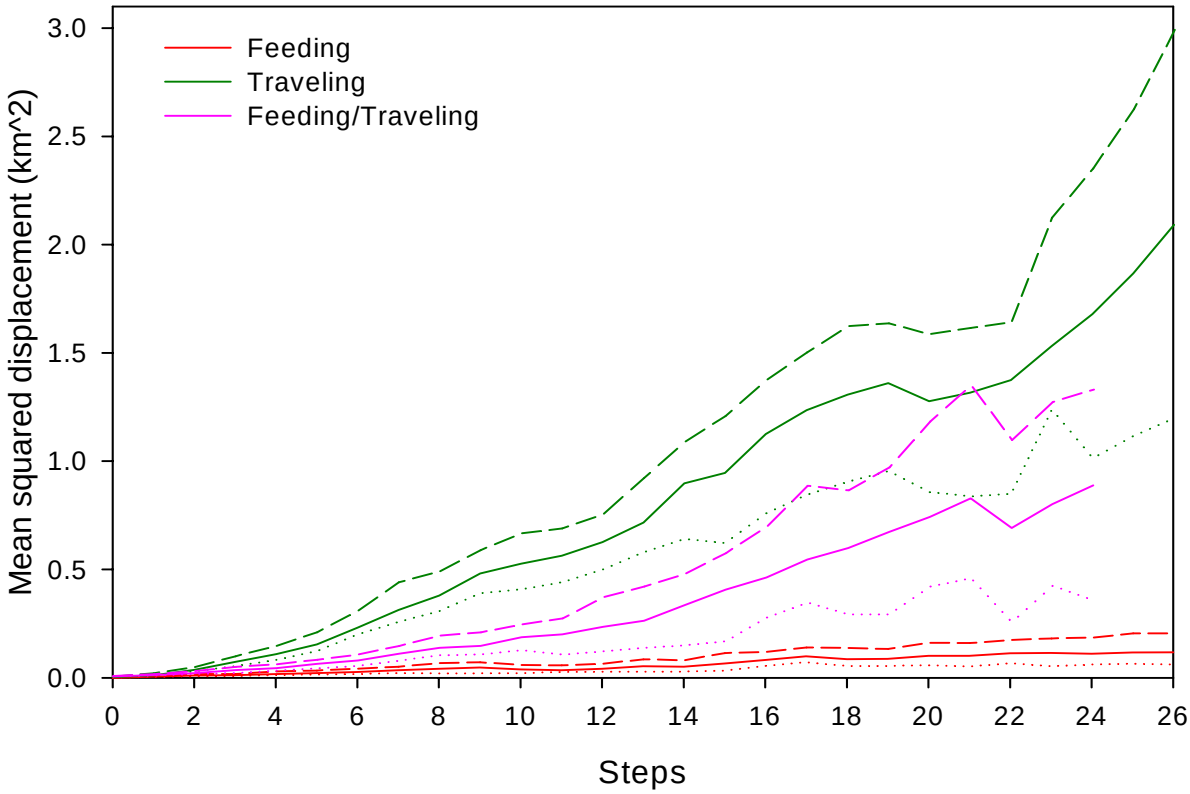


Figure 30. Mean squared displacement of western gray whales during three behavioral states. The upper and lower 95% confidence intervals are represented by dashed and dotted lines, respectively.

Killer Whales

Two groups of killer whales were observed in the study area during the 2003 field season. On 4 September 2003, a group of two killer whales was sighted at our 2nd Station traveling north. During the previous and following scans conducted, no gray whales were observed in the study area. Another group of killer whales consisting of three individuals traveling north and seven groups of gray whales were sighted during the previous scan in relation to the killer whale sighting. No changes in gray whale behavior were observed.

DISCUSSION

The observation seasons of 2002 and 2003 were markedly free of water-based industrial exploration and development activities to the north of the mouth of Piltun Lagoon, and we therefore believe that this year presented a second year of good "baseline"

information to help understand the biology, behavior, and habitat utilization of western gray whales on a daily, seasonal, and annual basis. As in the summers of 2001 and 2002 (see Würsig et al. 2002 and Würsig et al. 2003 for all comparisons), gray whales were mostly present on each day of the 30 days of observations and, on average, were 2.3 km from shore, indicating strong site fidelity to the nearshore area which is most likely due to high concentrations of prey availability (114.1 g/m^2 concentrations for Amphipods; Fedeev 2002, 2003). Such fidelity for feeding gray whales has also been described for the eastern population (for example, Pike 1962, Hatler and Darling 1974, Würsig et al. 1986, Dunham and Duffus 2002), as well as the present one (Weller et al. 1999). The mean of 2.0 whales per scan was slightly lower than the 2.6 and 3.2 mean number of whales per scan of 2001 and 2002, respectively. As well, the 1.6 pods per scan of 2003 was slightly lower than the 1.9 and 2.2 pods per scan of 2001and 2002. Mean pod size was 1.3 whales per pod, with a range of 1-4 (in 2001, pod size was 1.9; in 2002, pod size was 1.4). This small pod size is usual for bottom or near-bottom feeding gray whales, and is slightly less than the mean and median of two whales per pod reported for this population by Weller et al. (1999). Their data were gathered generally 10-25 km south of the present study area.

In 2001, considerably more whales occurred at the southern-most station, Mt. Kiwi, than at the four other more northerly stations. However, in 2002 and 2003, it was the northern-most station, Odoptu (just north of the 2001 northern station, Muritai) that had substantially more whales than did the other three to the south. We do not know why this was so, although surmise (with no data, however) that prey distribution was a likely factor in determining whale distribution. An alternative explanation could be potential season shifts from the southern Piltun lagoon area to this more northern area; however more data are needed to evaluate potential seasonal patterns. In the earlier part of the 2001 season, seismic surveys were conducted in the Odoptu Block, and some whales may have avoided this area during that period (Yazvenko et al. 2002).

While statistical analyses were not possible for whale and pod distribution intra-seasonally, an examination of Figure 6 indicates that the overall distribution did not change dramatically between late August and mid-September. By the last day, 14 September 2003, there was no indication that whales were moving south, i.e. that the fall migration had begun. As in 2001 and 2002, approximately equal numbers of whales and pods were seen in the

morning and afternoon, so there was no consistent movement into or out of the area on a diel basis.

Theodolite tracking demonstrated three major behavioral types: 1) feeding in an area where animals remained in a localized area of about 300 to 500 m for up to several hours; 2) feeding/traveling; and 3) traveling through the area, often parallel with the coastline. Unlike 2001 and 2002, more social activity was observed towards the end of August and early September, which corresponds with the apparent seasonal increase of social activity reported by several authors for August to September on eastern gray whales in the northern Bering Sea, summarized by Würsig et al. (1986). During two different occasions (26 August and 2 September 2003, Odoptu Station) of social activity, the penis of at least one whale was observed out of the water multiple times. Although such potential mating behavior has been observed for the eastern gray whales, the function and importance of this activity is unknown (Jones and Swartz 2002).

Overall, speed of travel of whales was at a median of about 2.1 and mean of 2.3 kph, somewhat slower than the 2002 (median 3.0 and mean 3.1) and slightly faster than 2001 (median = 1.5 and mean = 1.7), and comparing reasonably well with the 2.3 to 2.8 kph found from a limited set of three tracks in the northern Bering Sea (Würsig et al. 1986). The slightly slower speed compared to the 2002 data and to the eastern population data indicates that whales may have been feeding more, and traveling less between sites, than observed in 2002. These decreased speeds could also indicate that the gray whales were feeding more on benthic prey than "clouds" of water column prey, potentially distributed in somewhat poisson ("rare and random") fashion. Linearity, acceleration, reorientation rate, and mean vector length were all remarkably similar to the data of 2001 and 2002, gathered in nearly the same area (Table 10). Although Table 10 also presents data from off Piltun from two earlier years, we do not regard these to be closely comparable, since they were taken from a very different vantage point (the Piltun lighthouse), by different people than those who collected the data for the most recent two years, and by different categorizations and analytical approaches.

Blow intervals, blows per surfacing, and surface time were similar to these parameters for bottom-feeding eastern gray whales in the northern Bering Sea (Würsig et al. 1986) and off Vancouver Island, Canada (Guerrero 1989). Dive times were intermediate to the 2.5 and 1.8 minutes observed in 2001 and 2002, respectively. Würsig et al. (1986) found

a general increase in dive time in deeper (> 20 m) water. These lower dive times are possibly due in part to the very shallow nature of the Sakhalin Island nearshore areas. Guerrero (1989) found that gray whales feeding on mysids in the water column have fewer numbers of blows per surfacing and shorter blow intervals, surface times, and dive times than bottom-feeding whales. The dive-surface blow rate was also closer to mysid feeders (Guerrero 1989) than eastern gray whale bottom feeders, but this – as well – may be due to the shallowness of the Piltun feeding area, fewer observed feeding bouts (and more traveling behavior), or some other factor(s).

An analysis was conducted to compare the three primarily observed behavioral states (feeding, feeding/traveling, and traveling). Although western gray whale movements were significantly different for speeds, reorientation rates, linearity, mean vector length, ranging index, blow interval, and dive-surface blow rate, sample sizes were relatively small (N_{max} = 22 - N_{min} = 8) for each of the observed behaviors. More data are required to understand these natural movements and respiration patterns among these different behavioral activities.

In summary, there is some "natural" variability among western gray whales while on the feeding grounds, and we urge further exploration of the complex suite of natural and anthropogenic variables that can affect the whales on an annual, seasonal, and geographic basis. Comparison of data between 2002 and 2003, which were both baseline years for this study area with little anthropogenic activity, indicate differences in behavior which could potentially be due to changes in prey availability. Two important missing items for the present work are: 1) a complete environmental data set as supplied to us for the 2001 analysis; and 2) knowledge of whale prey. Benthic and prey studies have been conducted in both 2002 and 2003 (Fadeev 2003, 2004) and additional analyses overlaying density of prey with behavioral observations are recommended to further understand western gray whale behavior. Since there is the possibility of cumulative impacts on the whales as oil/gas industrial projects develop in the future, it is important to conduct studies to fill in the missing information on life history, behavior, and habitat utilization. In addition, monitoring to identify problems and suggest alternatives to management practices that may be impacting the whales need to continue.

Table 10. Summary statistics for theodolite and focal behavior data collected during 1997, 1998, and 2001 - 2003. Dashes (-) separate numbers that indicate ranges; plus/minus (±) separate means and standard deviations, and numbers in parentheses are sample sizes.

Variable	1997 (Würsig et al. 1999)	1998 (Würsig et al. 2000)	2001 (Würsig et al. 2002)	2002 (Würsig et al. 2003)	2003 (Present Report)
Leg Speed (kph)	1.5-2.0	1.7± 1.4	1.9 ± 1.49 (510)	3.2 ± 2.06 (74)	2.3 ± 1.04 (47)
Linearity	0.70 - 0.90	0.78± 0.40	0.8 ± 0.23 (482)	0.8 ± 0.24 (74)	0.8 ± 0.29 (47)
Acceleration (kph)	-	-	0.0 ± 0.71 (506)	0.1 ± 0.50 (74)	0.0 ± 0.23 (47)
Reorientation Rate (°/min.)	8 – 13	7.0± 6.12	17.4 ± 13.72 (506)	21.0 ± 19.32 (74)	26.0 ± 18.76 (47)
Distance to Shore (km)	1 – 3	<1 – 2	1.1 ± 0.66 (510)	-	2.3 ± 1.23 (283)
Mean Vector Length	-	-	0.8 ± 0.26 (482)	0.8 ± 0.27 (74)	0.7 ± 0.29 (47)
Ranging Index	-	-	-	-	31.1 ± 18.06 (47)
Blow Interval (blows/min.)	0.46± 0.17	0.37± 0.196	0.4 ± 0.14 (271)	0.5 ± 0.19 (46)	0.4 ± 1.33 (34)
Blows per Surfacing	4.7± 4.33	3.7± 2.24	5.2 ± 3.93 (234)	4.9 ± 4.45 (42)	4.2 ± 1.38 (34)
Surface Time (min.)	1.8± 2.48	1.0± 1.03	1.6 ± 1.84 (241)	1.7 ± 1.50 (42)	1.7 ± 1.78 (34)
Dive Time (min.)	1.7± 0.53	2.3± 0.99	2.5 ± 0.92 (239)	1.8 ± 0.80 (44)	2.2 ± 0.77 (34)
Dive-Surface Blow Rate	1.2± 0.40	1.1± 0.43	1.2 ± 0.34 (236)	1.3 ± 0.32 (42)	1.3 ± 0.42 (34)

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APPENDIX 1. Theodolite Calculations of Distance, Bearing, and Geographic Positions (taken from Gailey and Ortega-Ortiz 2002).

The distance calculation performed for each fixed object incorporates the station's geographic position (latitude, longitude), theodolite angle readings, observer's height above sea level, and tide height. We used a modified version of the distance approximation proposed by Lerczak and Hobbs (1998) to calculate sighting distances from angular readings of shore-based marine mammal surveys, which corrects for the curvature of the earth.

$$\beta = \frac{\pi}{2} - \alpha - \theta = 180 - \varpi$$

$$D_0 = (R_E + h)\cdot\cos(\beta) - \sqrt{(R_E + h)^2 \cdot \cos(\beta)^2 - (2hR_E + h^2)}$$

$$\delta = \arcsin\left(\sin(\beta)\frac{D_0}{R_E}\right)$$

$$D = \delta \cdot R_E$$

where,

α = angle from horizontal (90°) to horizon and central arc angle from horizon to station

β = angle from object being fixed to station

δ = central arc from object being fixed to station

θ = angular drop from horizon to object being fixed

ϖ = vertical angle estimated with the theodolite

h = station height or altitude

R_E = radius of the Earth $(6.371\times10^6 \text{ m})$

D_0 = line-of-sight distance to object being fixed

D = distance to object being fixed along the surface of the earth/ocean

Once the distance to the object along the surface of the ocean (D) is known, the great circumference equation is used to determine geographic position of the fixed object,

$$\tau = \eta - \rho$$

$$Lat_F = \sin^{-1}\left(\cos(\tau)\cdot\sin(D/60/1852)\cdot\cos(Lat_S) + [\sin(Lat_S)\cdot\cos(D/60/1852)]\right)$$

$$Lon_F = \cos^{-1}\left(\frac{\cos(D/60/1852) - [\sin(Lat_S)\cdot\sin(Lat_F)]}{\cos(Lat_S)\cdot\cos(Lat_F)}\right) + Lon_S$$

where,

D = distance in meters between the two points along the surface of the Earth

τ = bearing from station to object

η = azimuth or horizontal angle estimated with the theodolite

ρ = reference azimuth (bearing from station to reference point)

Lat_S = latitude of the station

Lon_S = longitude of the station

Lat_F = latitude of the fixed object

Lon_F = longitude of the fixed object

The great circumference equation is also used to determine distance between two geographic points along the surface of the earth when the geographic coordinates (latitude and longitude) of both points are known.

$$D = \left(60\cdot\cos^{-1}\left[(\sin(Lat_1)\cdot\sin(Lat_2)) + (\cos(Lat_1)\cdot\cos(Lat_2))\cdot\cos(Lon_2 - Lon_1)\right]\right)\cdot 1852$$

$$\varphi = \cos^{-1}\left[\frac{\sin(Lat_2) - [\sin(Lat_1)\cdot\cos(D/60)]}{\sin(D/60)\cdot\cos(Lat_1)}\right]$$

where,

D = distance in meters between the two points along the surface of the Earth

φ = bearing from point 1 to point 2

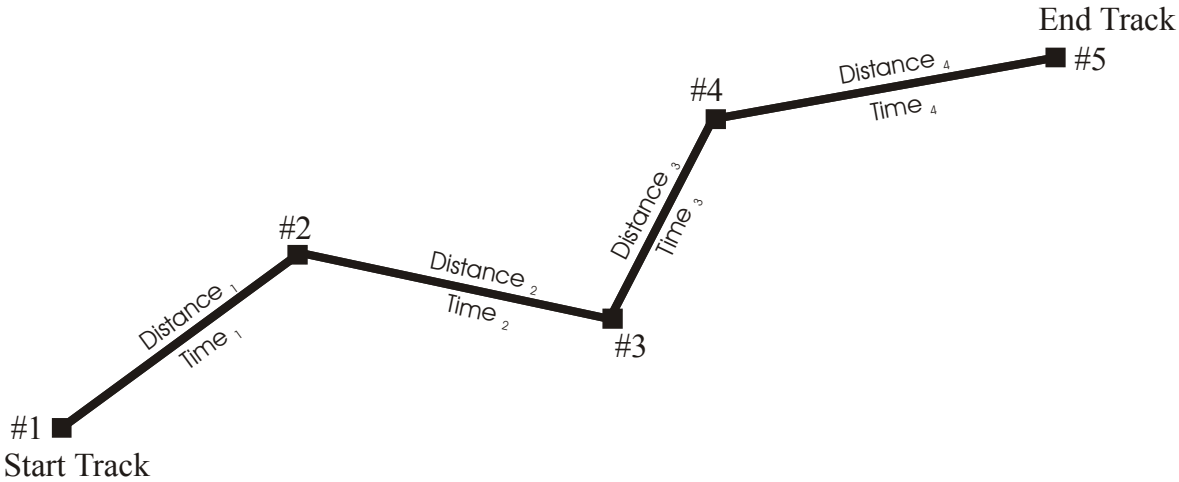
Lat_1 = latitude of point

Lon_1 = longitude of point 1

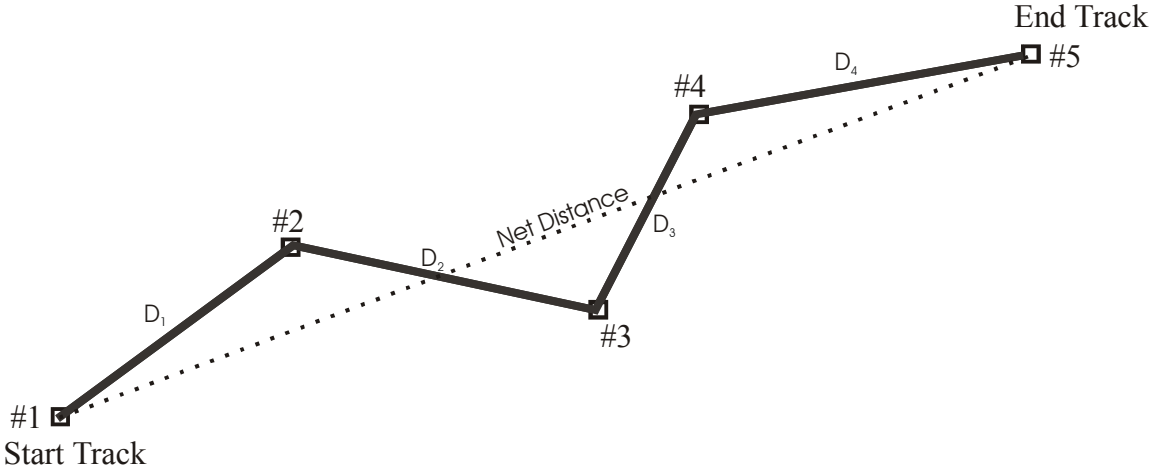
Lat_2 = latitude of point 2

Lon_2 = longitude of point 2

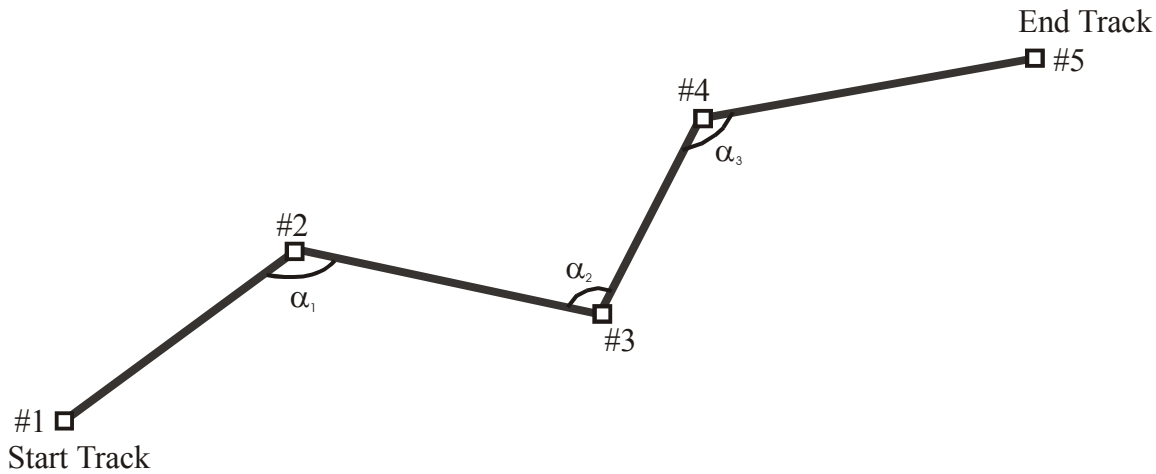
APPENDIX 2. Examples of Trackline Calculations for Leg Speed, Linearity, Reorientation Rates, and Relative Orientation (taken from Gailey and Ortega-Ortiz 2002).



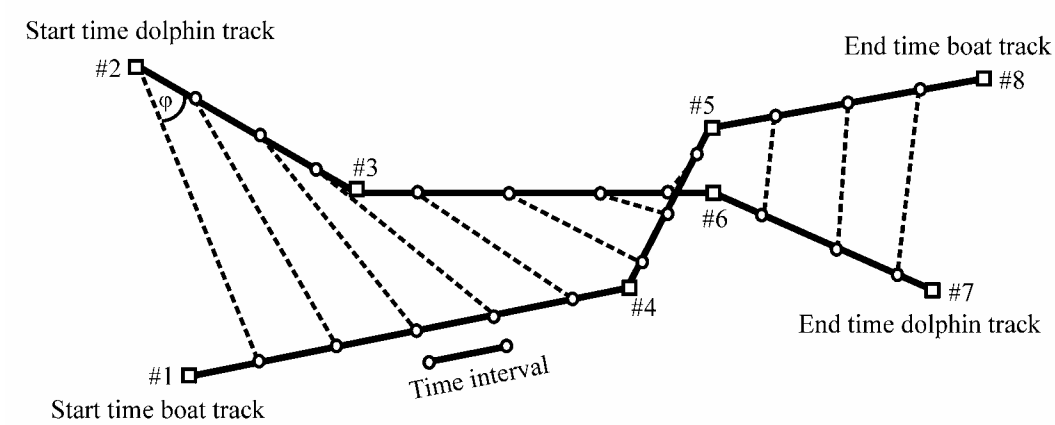
An example illustrating the calculated leg speed by dividing the geographic distance travelled between two sequential fixed positions by time. Numbers indicate actual fix points along the trackline ($Leg\ \ Speed = \text{Distance}_i / \text{Time}_i$, where Distance_i is the distance between fix number i and i+1 and Time_i is the time difference between fix number i and i+1).



An example illustrating the calculated linearity by dividing the net geographic distance by the cumulative distances along a trackline. Numbers indicate actual fix points along the trackline ($Linearity = Net_D \Big/ \sum_{i=1}^{k-1} D_i$, where D_i is the distance between fix number i and i+1, k is the maximum number of fix points, and Net_D is the net distance between the first and last fix points).



An example illustrating the calculated reorientation rate. ($RR = \sum_{i=1}^{k-1} |\alpha_i - \alpha_{i+1}| \Big/ Time_D$, where RR is the reorientation rate, $Time_D$ is the duration of the trackline (minutes), and k is the total number of angles). Numbers indicate actual fix points along the trackline.

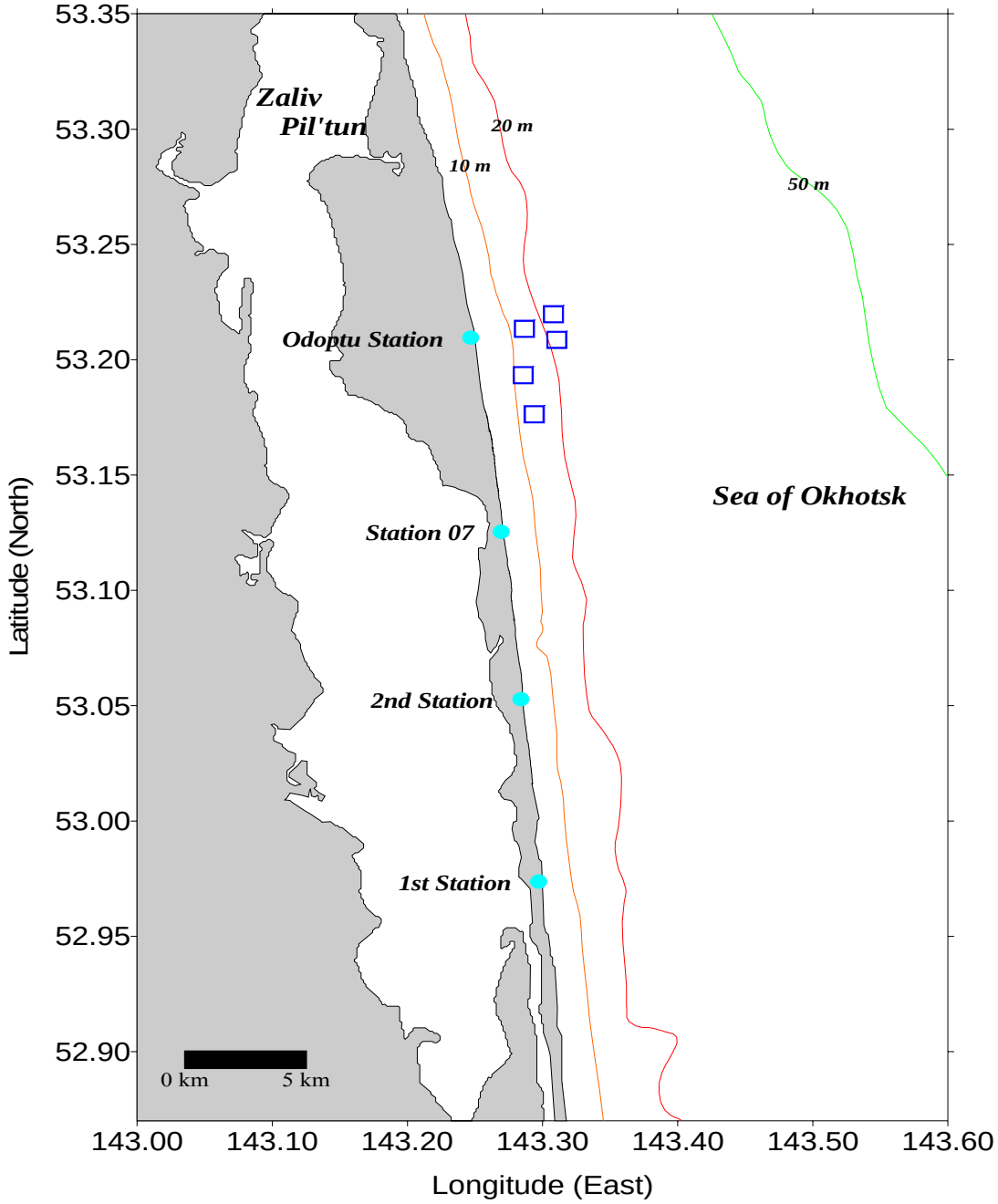


Positions used to estimate distance between a dolphin/whale trackline and a boat trackline. Location is estimated by interpolating position at specified time intervals. Numbers indicate the sequence of actual fixes. The angle φ indicates the relative orientation of reference trackline (dolphin/whale) to trackline selected for comparison (vessel).

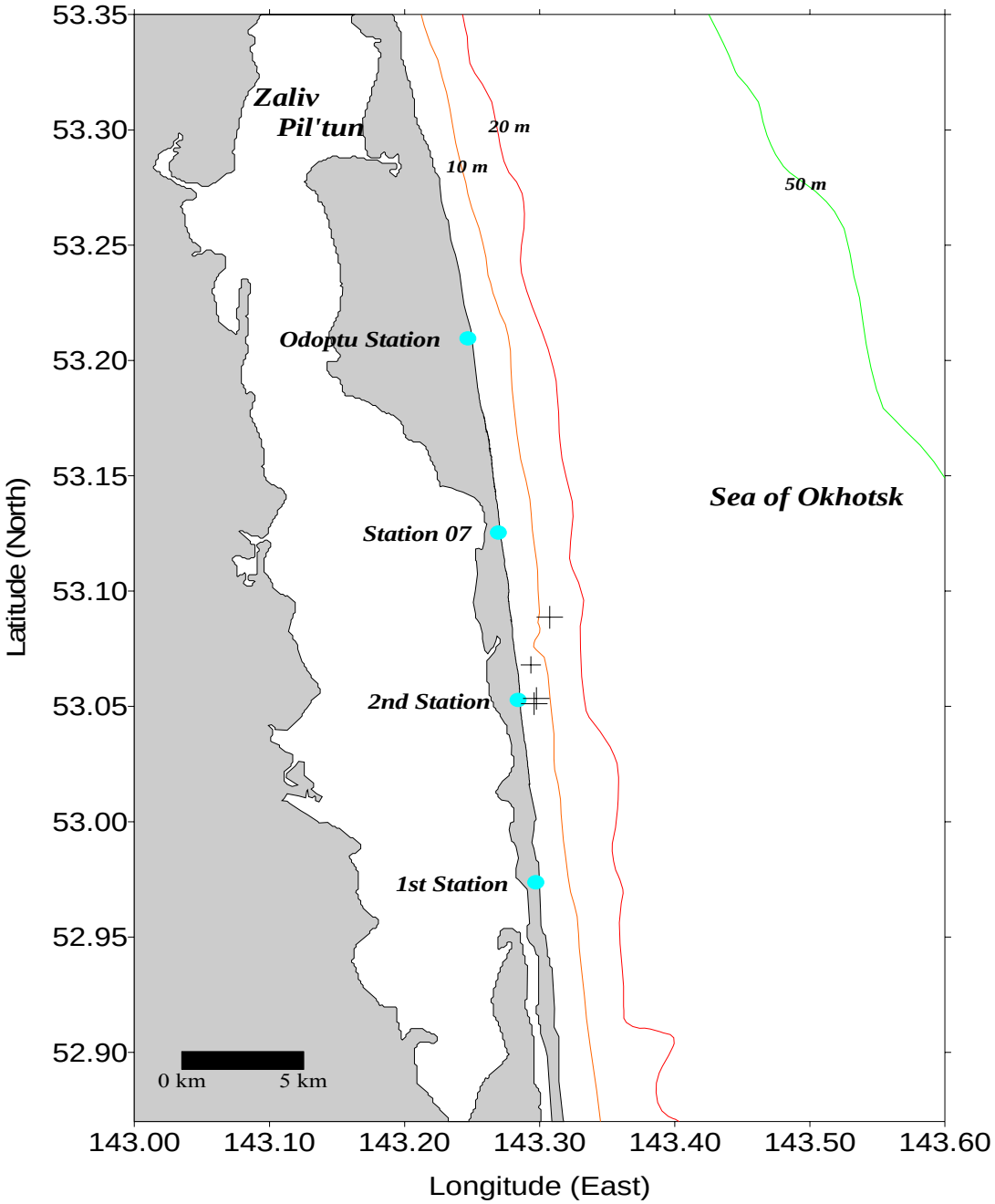
APPENDIX 3. Daily summary of theodolite, focal behavior, and scan data collected during the summer of 2003.

Station	Date	Start Day	End Day	Effort (hrs)	# Tracklines	# Focal Follows	# Scans
1st_Station	20-Jul-03	17:13:29	17:36:20	0.38	0	0	1
Odoptu_Station	22-Jul-03	7:24:41	15:46:15	8.35	0	0	6
1st_Station	29-Jul-03	7:47:20	8:44:23	0.95	1	1	1
1st_Station	8-Aug-03	12:04:30	12:59:40	0.92	0	0	1
1st_Station	13-Aug-03	6:40:11	9:12:10				
1st_Station	13-Aug-03	10:05:03	18:44:30	11.18	6	2	7
2nd_Station	14-Aug-03	7:55:26	18:29:52	10.57	5	0	7
Station_07	15-Aug-03	8:10:00	10:57:30				
Station_07	15-Aug-03	11:48:10	18:25:17	9.40	0	0	6
Station_07	18-Aug-03	10:47:45	19:37:00	8.82	1	1	7
Station_07	19-Aug-03	6:37:50	16:51:30	10.22	1	1	7
Odoptu_Station	20-Aug-03	6:17:47	17:47:24	11.48	7	4	6
1st_Station	21-Aug-03	6:16:40	9:43:25				
1st_Station	21-Aug-03	10:50:16	18:42:40	11.32	5	2	8
2nd_Station	22-Aug-03	7:32:46	8:27:33				
2nd_Station	22-Aug-03	10:14:15	10:32:45	1.22	1	0	2
2nd_Station	23-Aug-03	6:17:35	13:34:14	7.27	7	4	4
Station_07	24-Aug-03	6:17:30	17:26:20	11.13	1	2	8
Station_07	25-Aug-03	6:18:13	17:30:22	11.20	1	1	7
Odoptu_Station	26-Aug-03	6:25:15	18:12:55	11.78	6	3	8
1st_Station	27-Aug-03	6:37:25	15:36:10	8.97	0	0	8
2nd_Station	28-Aug-03	7:34:50	14:44:15	7.15	0	0	6
Station_07	1-Sep-03	6:48:00	10:28:55	3.67	1	1	2
Odoptu_Station	2-Sep-03	6:56:32	15:45:30	8.80	6	2	2
1st_Station	3-Sep-03	6:42:45	18:09:26	11.43	2	2	11
2nd_Station	4-Sep-03	7:22:32	11:59:10				
2nd_Station	4-Sep-03	17:22:46	18:52:05	6.08	1	0	5
2nd_Station	5-Sep-03	7:02:26	18:59:10	11.93	5	2	8
Station_07	6-Sep-03	6:49:29	17:20:20	10.50	0	0	9
Odoptu_Station	7-Sep-03	6:46:52	17:29:48	10.70	8	3	7
1st_Station	8-Sep-03	6:48:50	16:41:30	9.87	0	0	9
2nd_Station	9-Sep-03	6:50:13	10:35:40	3.75	1	0	3
2nd_Station	10-Sep-03	7:09:38	9:35:36	2.42	0	0	2
Station_07	12-Sep-03	10:20:33	11:40:45				
Station_07	12-Sep-03	17:40:21	19:06:40	2.77	2	2	2
Station_07	13-Sep-03	7:08:08	15:50:07	8.68	5	3	7
TOTAL	30 Days			232.91	73	36	167

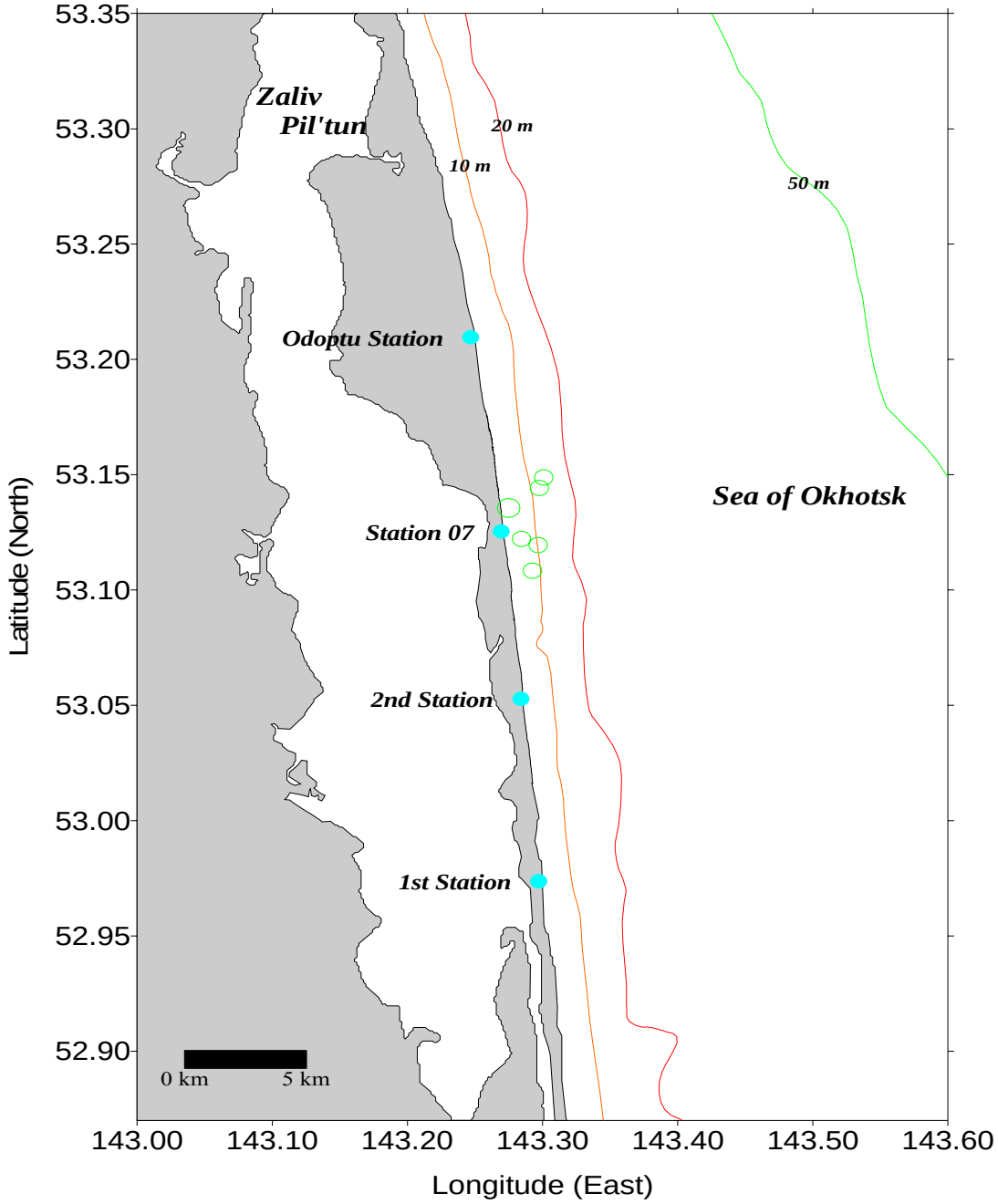
APPENDIX 4. Daily scan sampling plots of western gray whales during the summer of 2003.



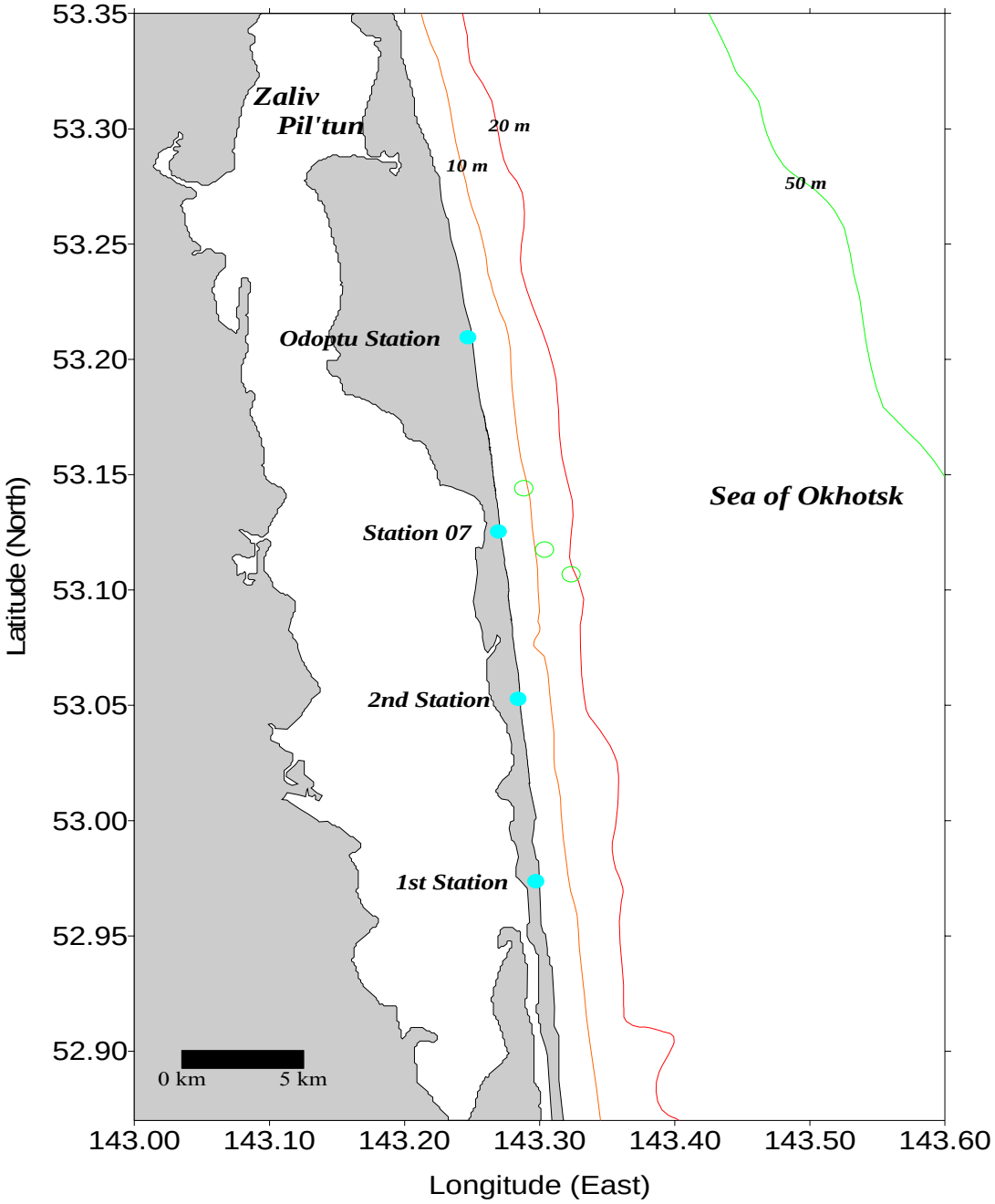
Station: Odoptu Station
Date: 22 July 2003
Number Scans: 6



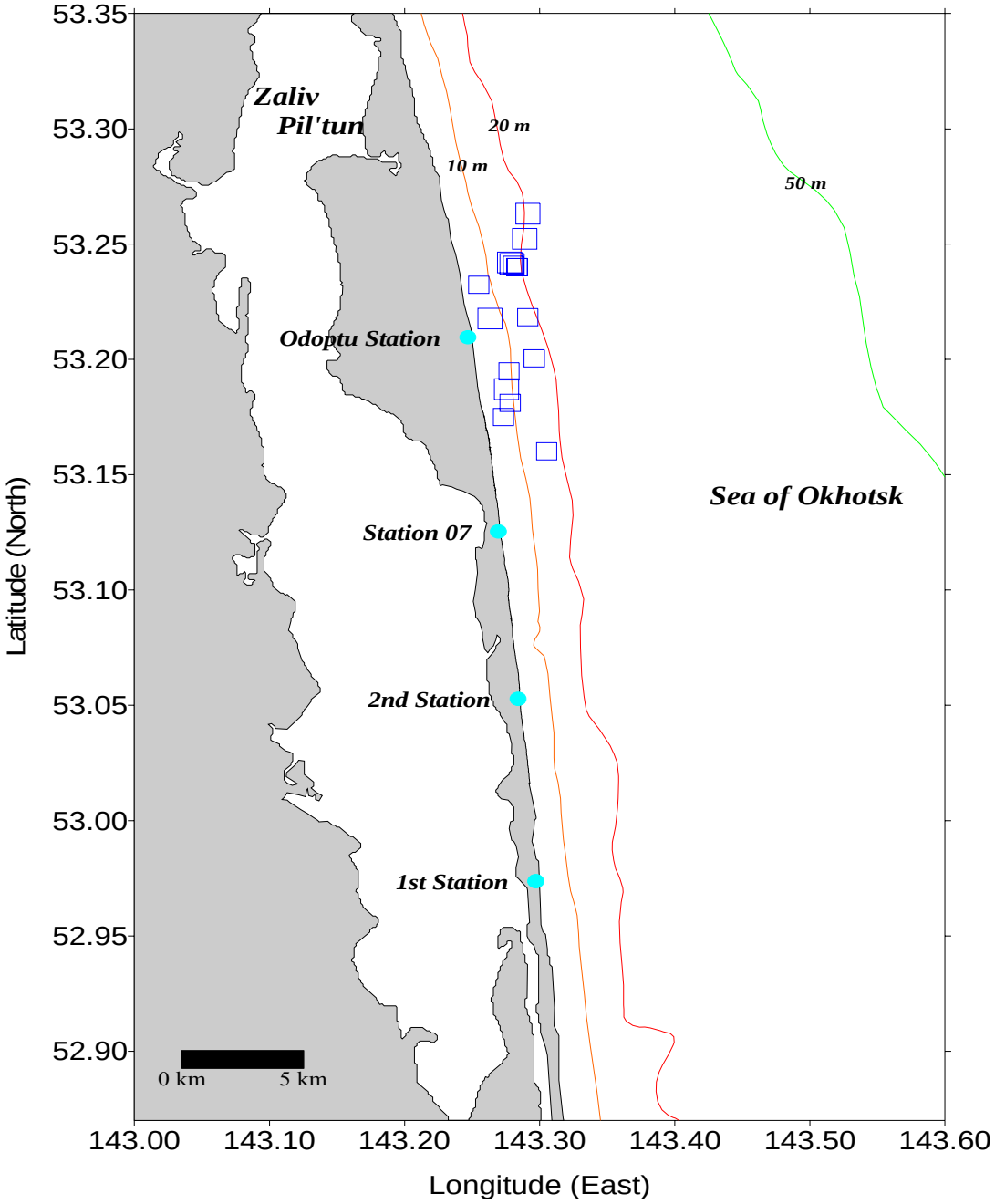
Station: 2nd Station
Date: 14 August 2003
Number Scans: 7



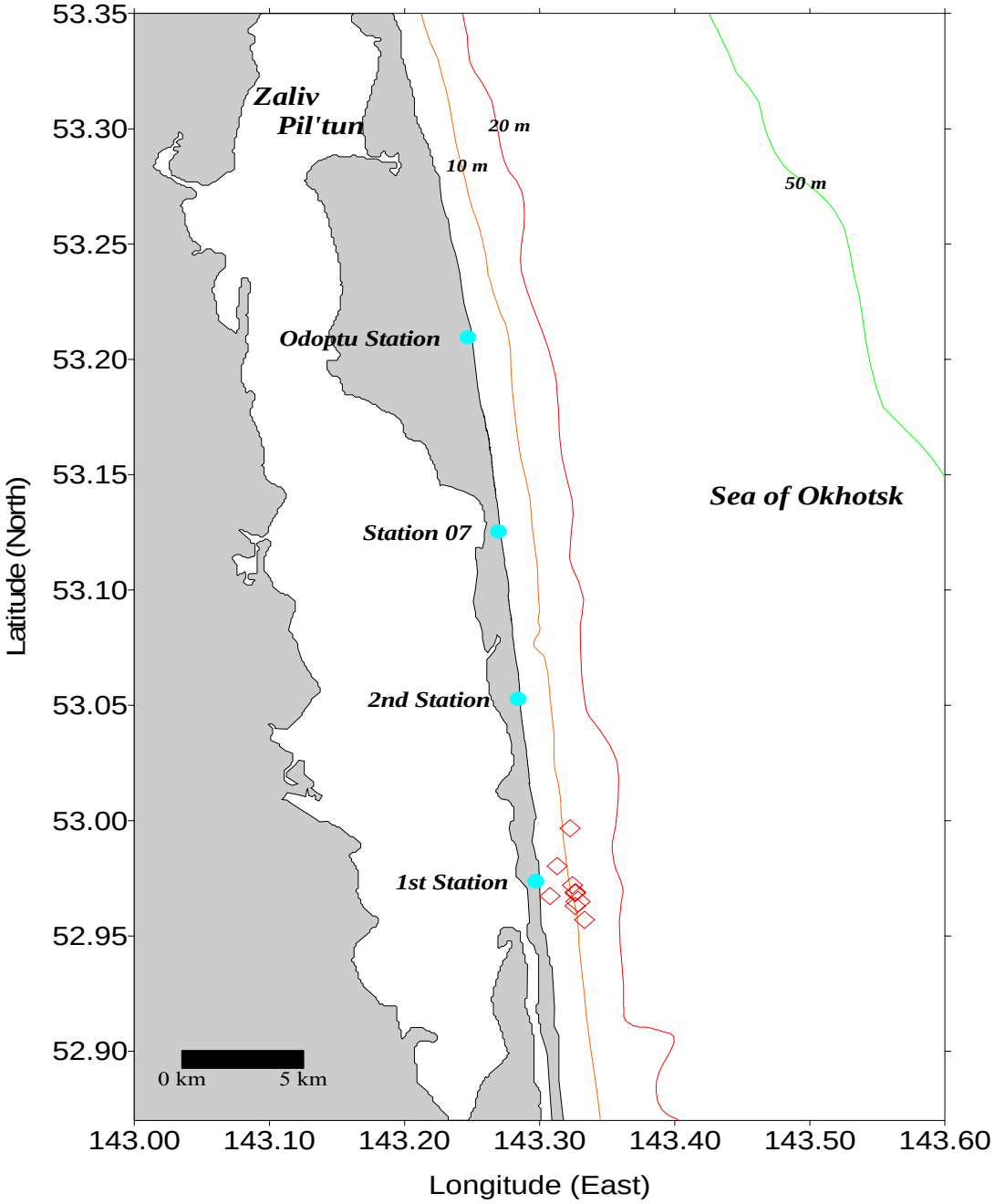
Station: Station 07
Date: 18 August 2003
Number Scans: 7



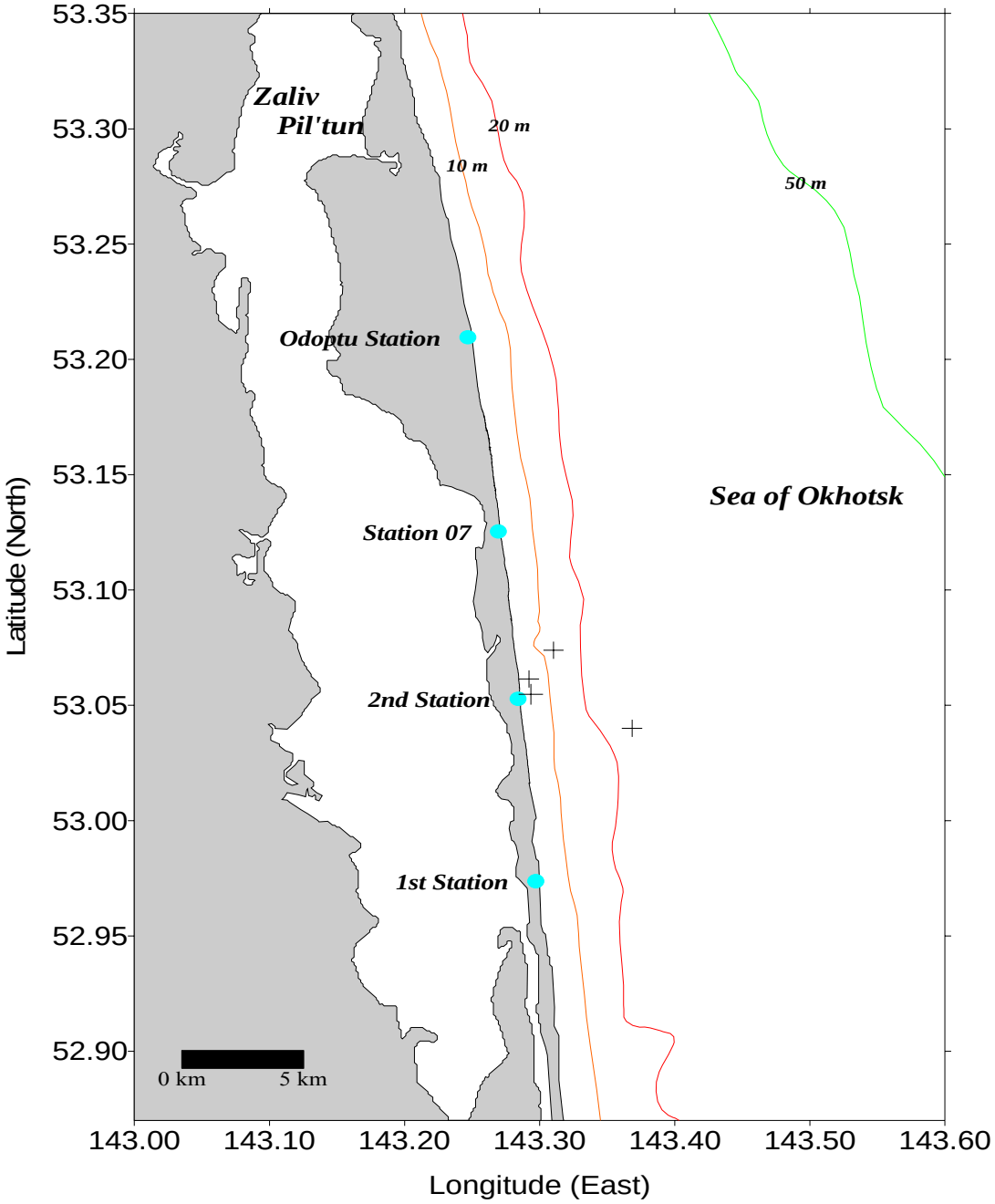
Station: Station 07
Date: 19 August 2003
Number Scans: 7



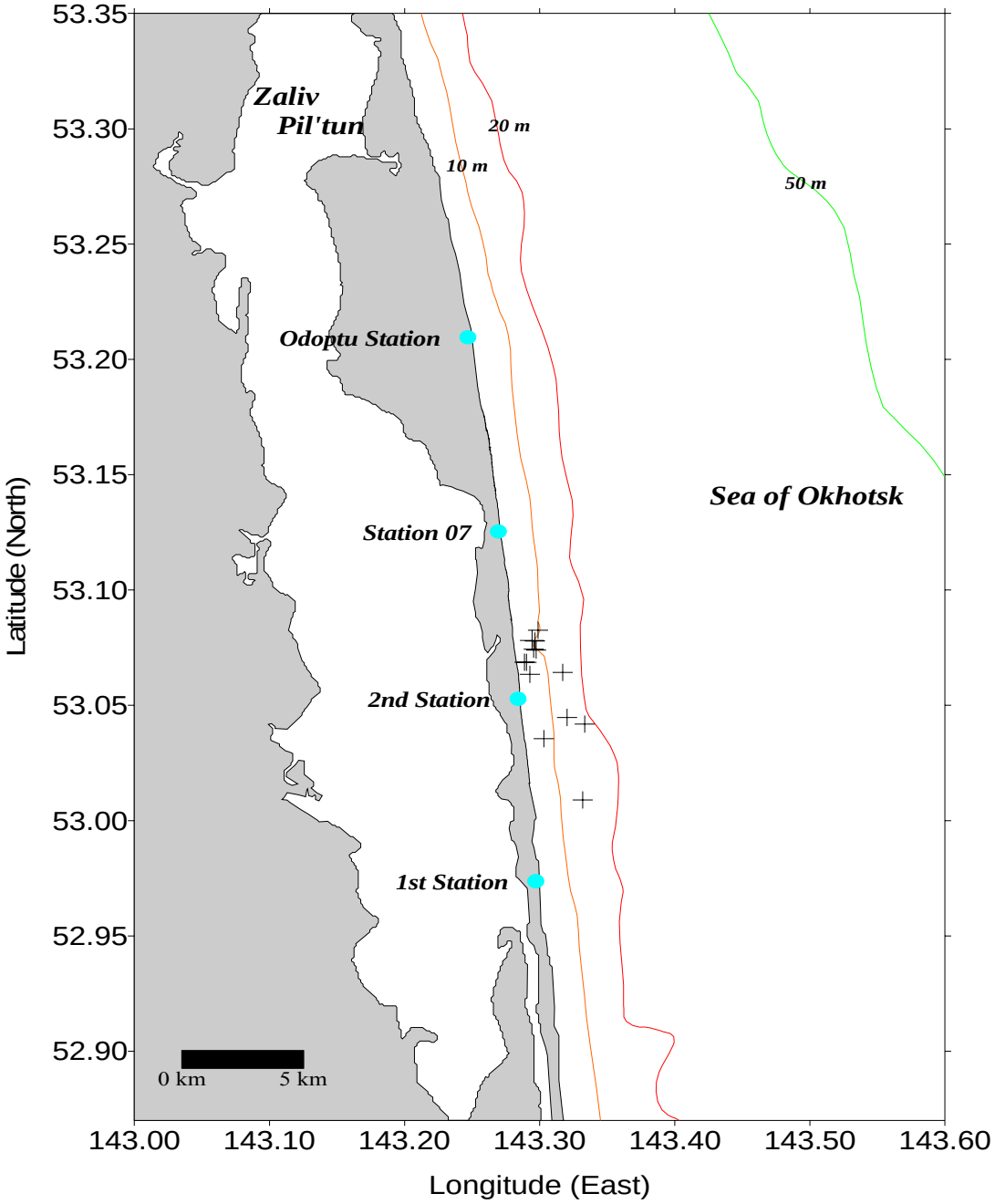
Station: Odoptu Station
Date: 20 August 2003
Number Scans: 6



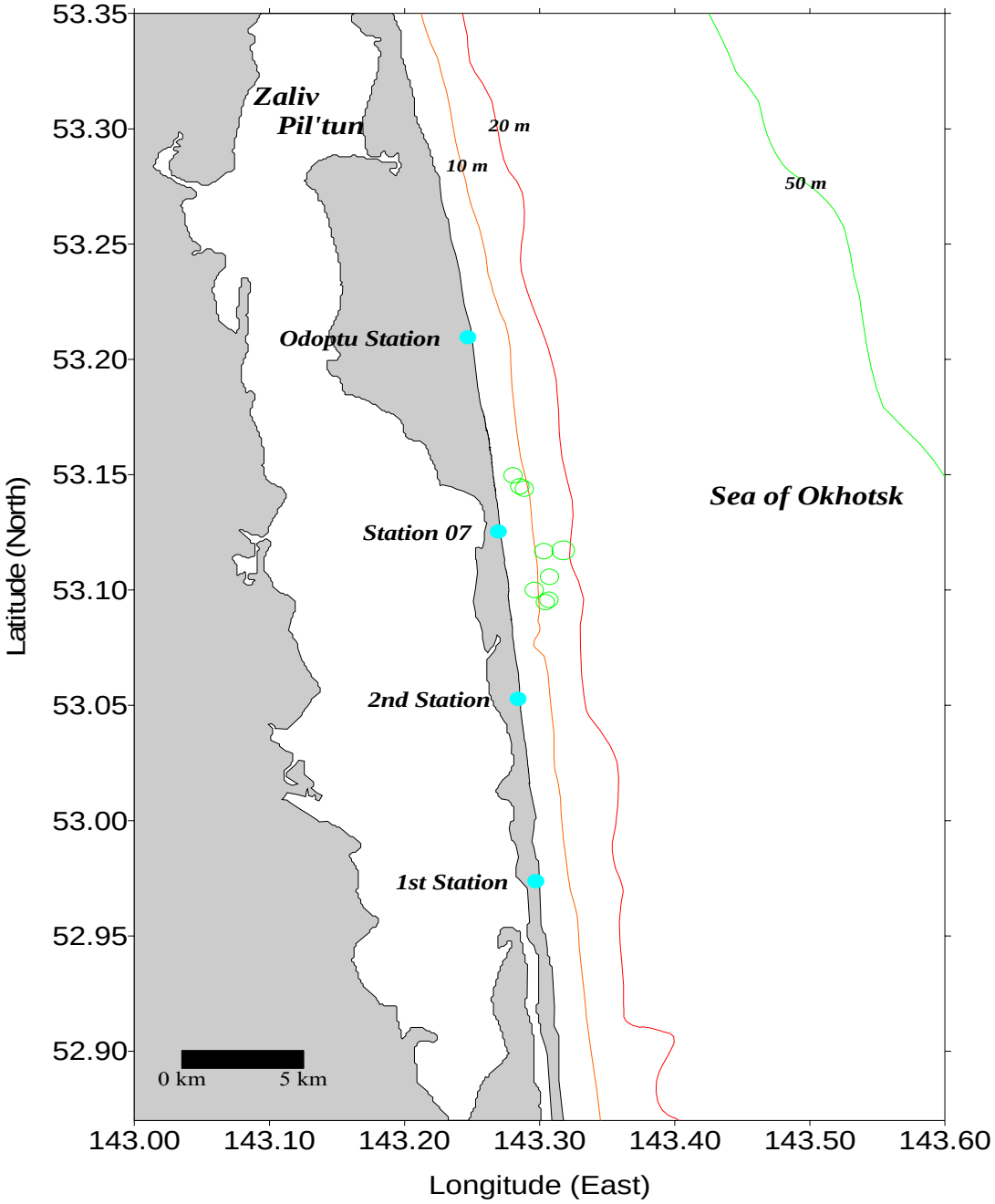
Station: 1st Station
Date: 21 August 2003
Number Scans: 8



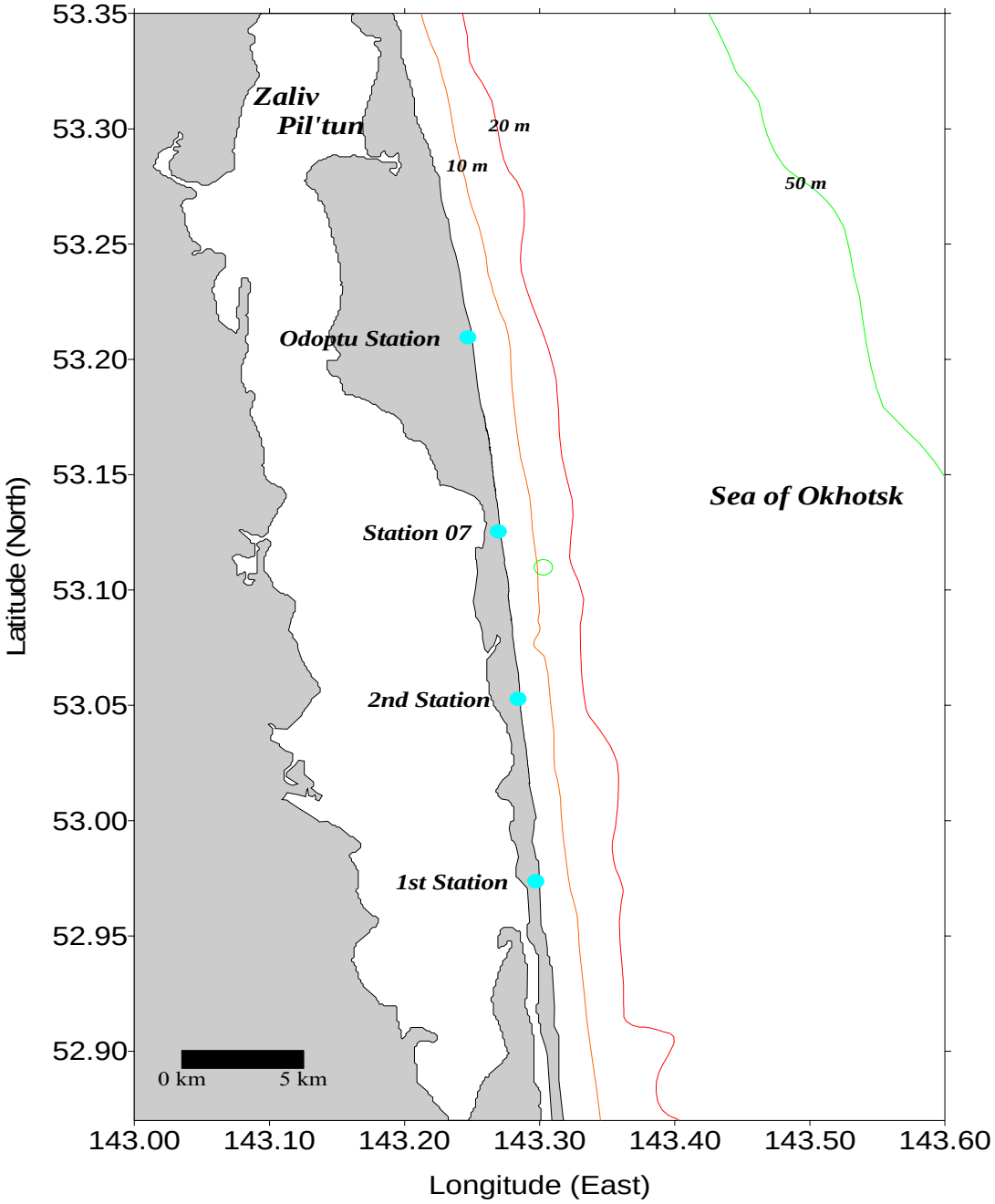
Station: 2nd Station
Date: 22 August 2003
Number Scans: 2



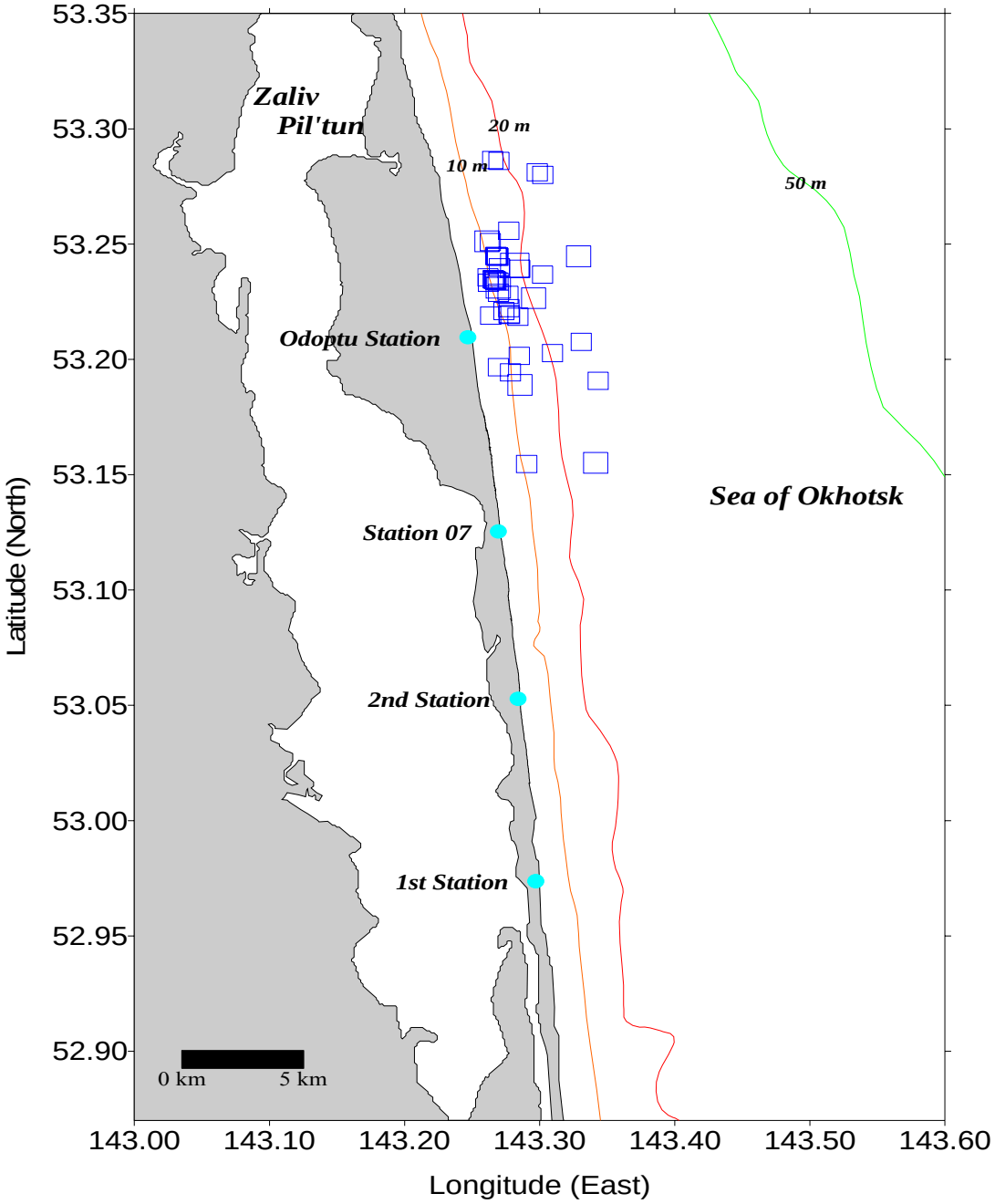
Station: 2nd Station
Date: 23 August 2003
Number Scans: 4



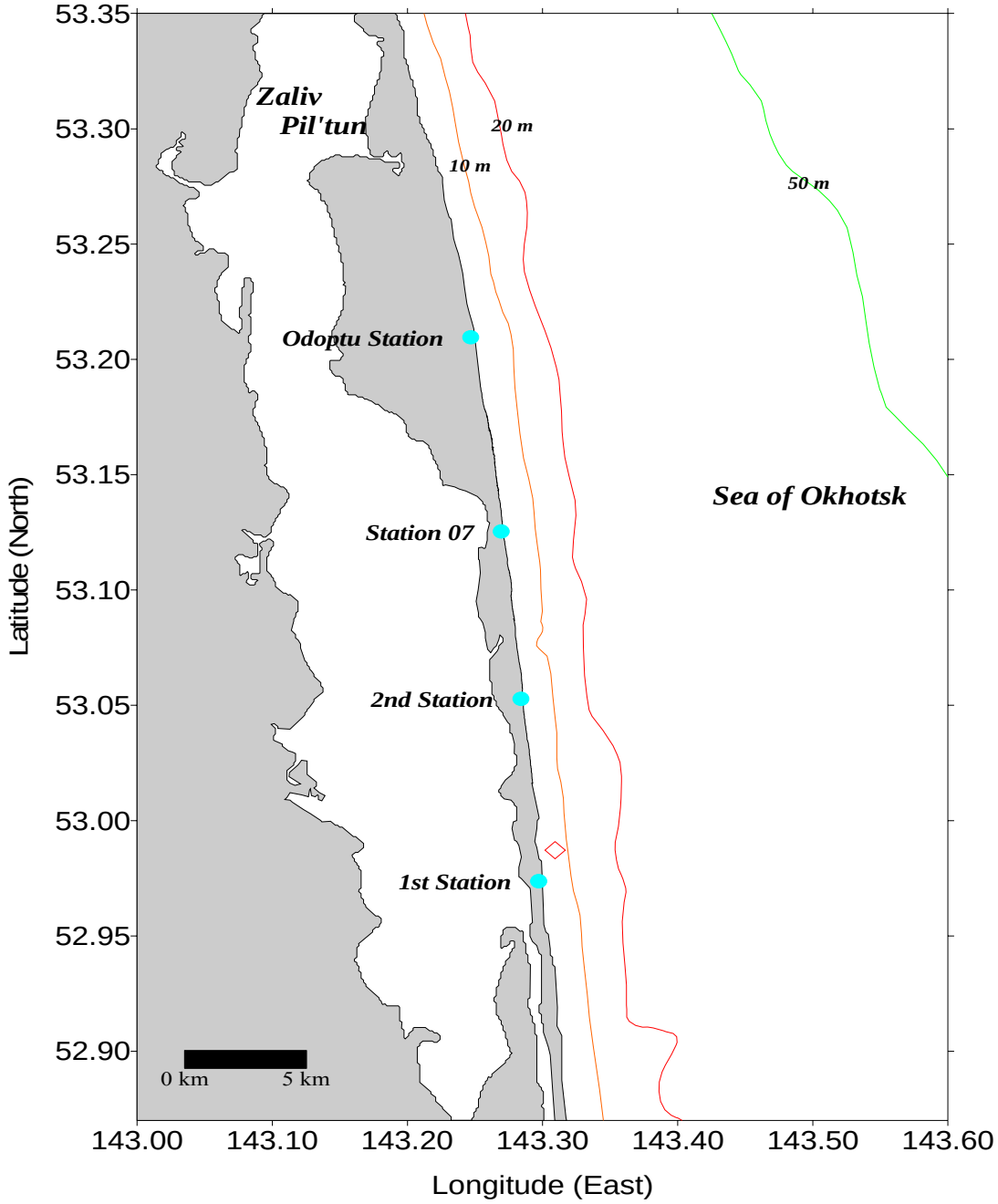
Station: Station 07
Date: 24 August 2003
Number Scans: 8



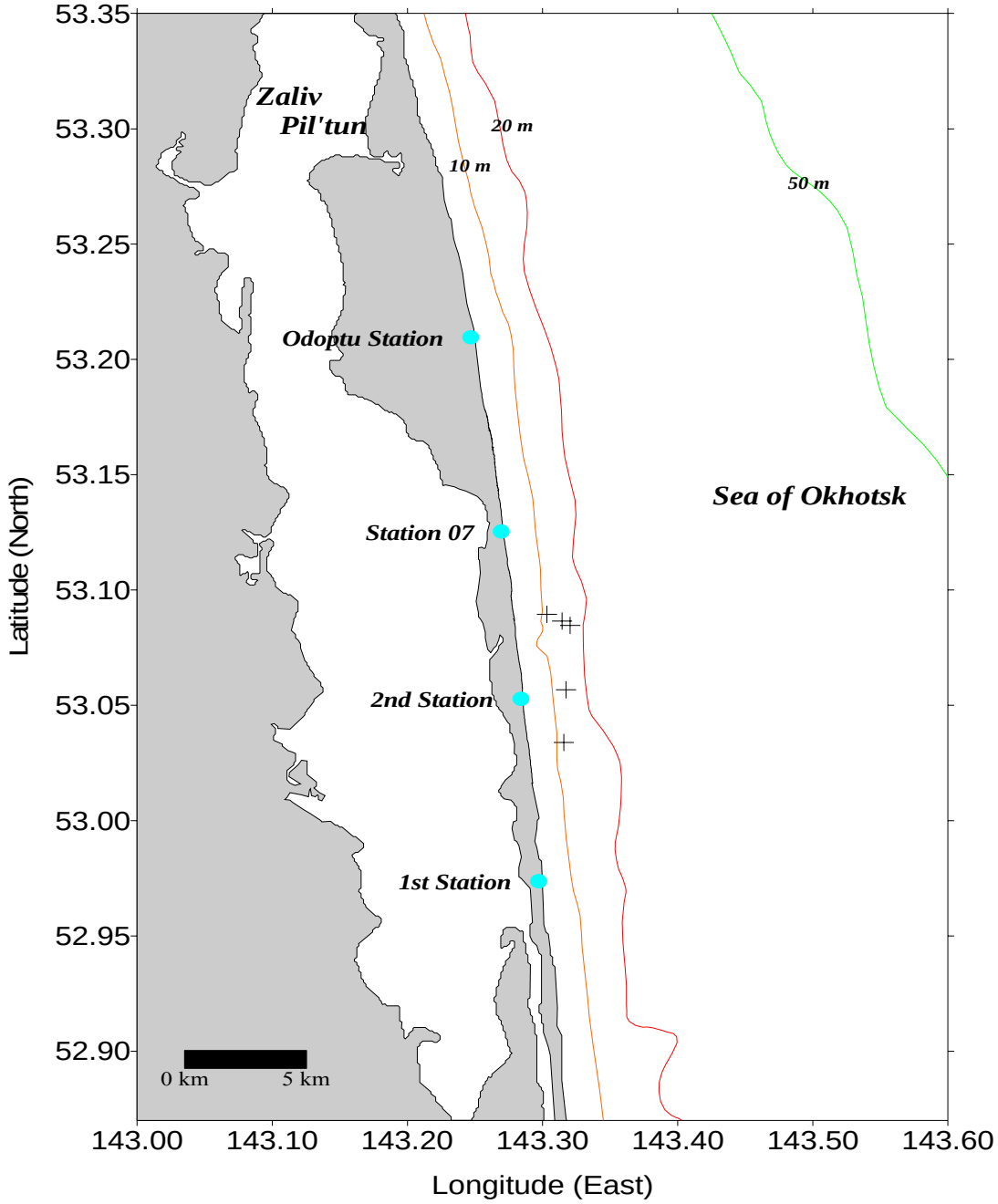
Station: Station 07
Date: 25 August 2003
Number Scans: 7



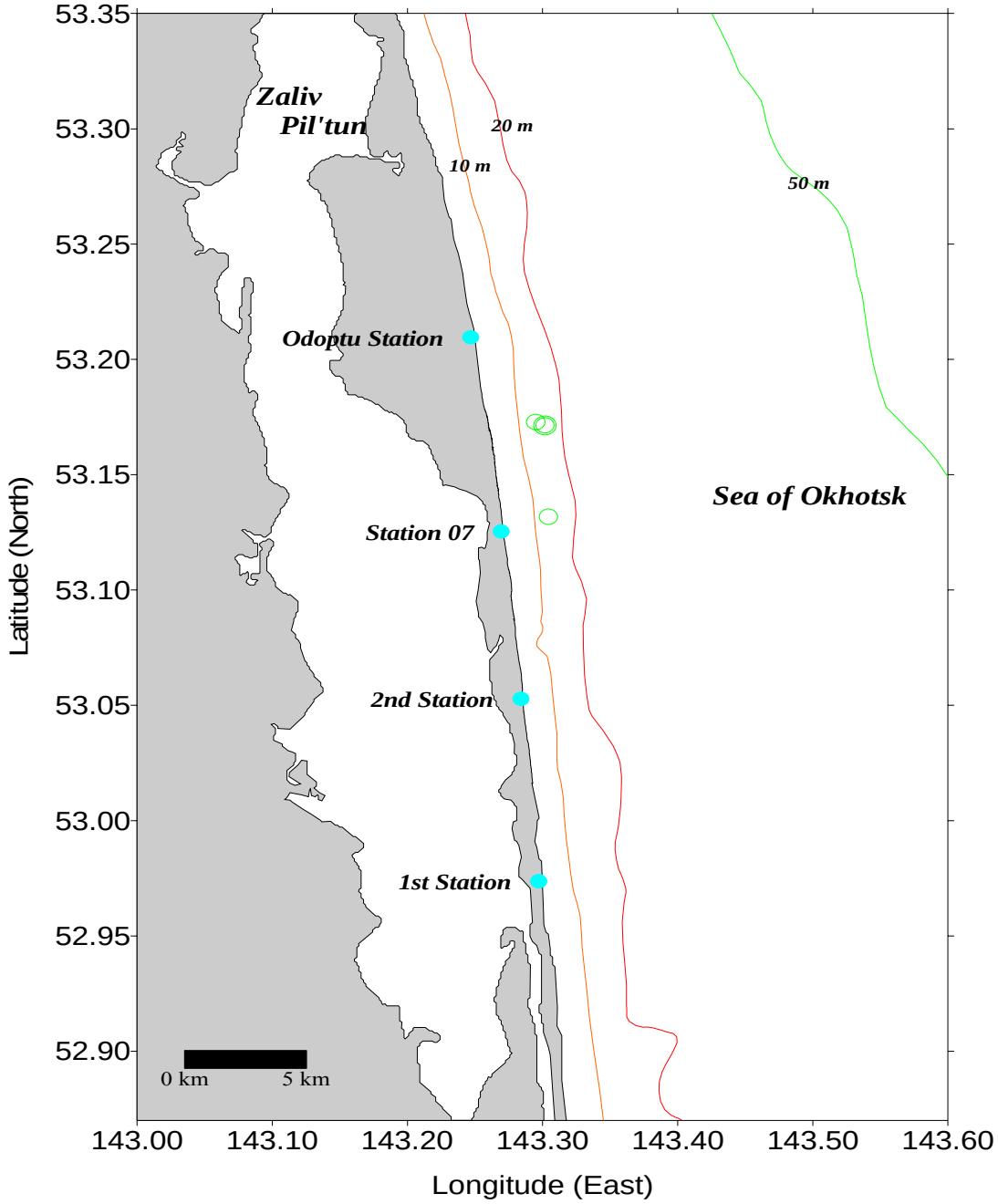
Station: Odoptu Station
Date: 26 August 2003
Number Scans: 8



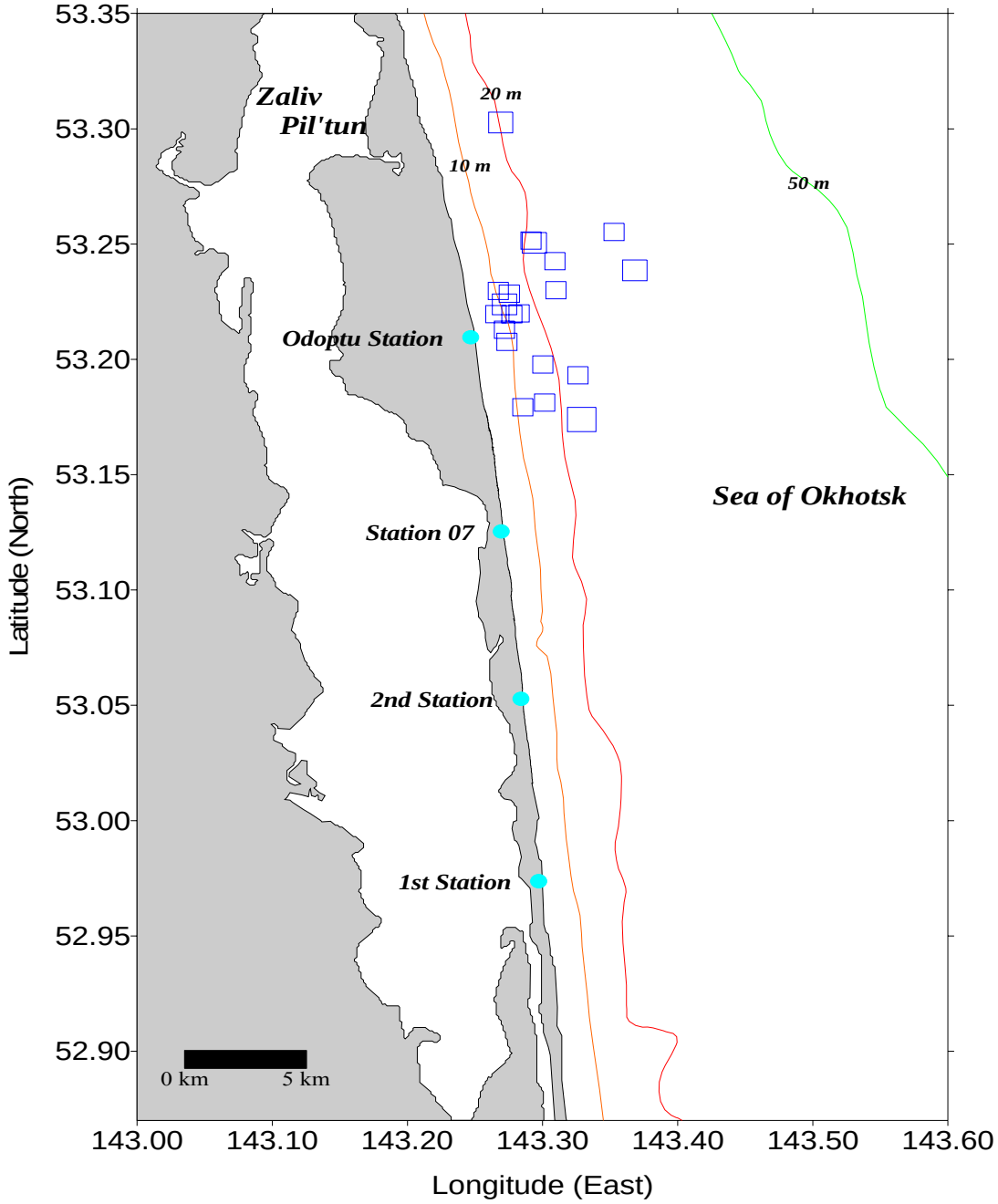
Station: 1st Station
Date: 27 August 2003
Number Scans: 8



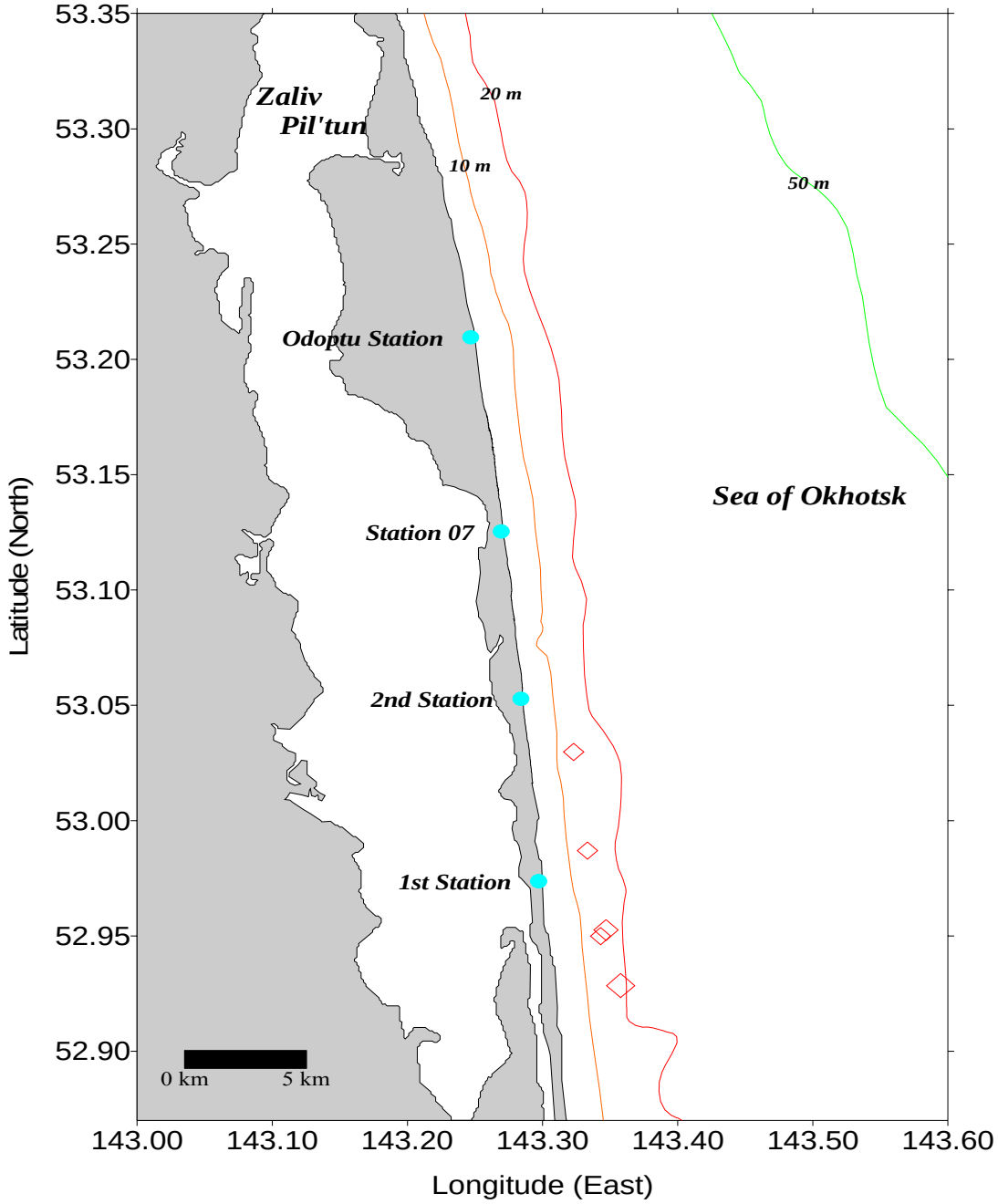
Station: 2nd Station
Date: 28 August 2003
Number Scans: 6



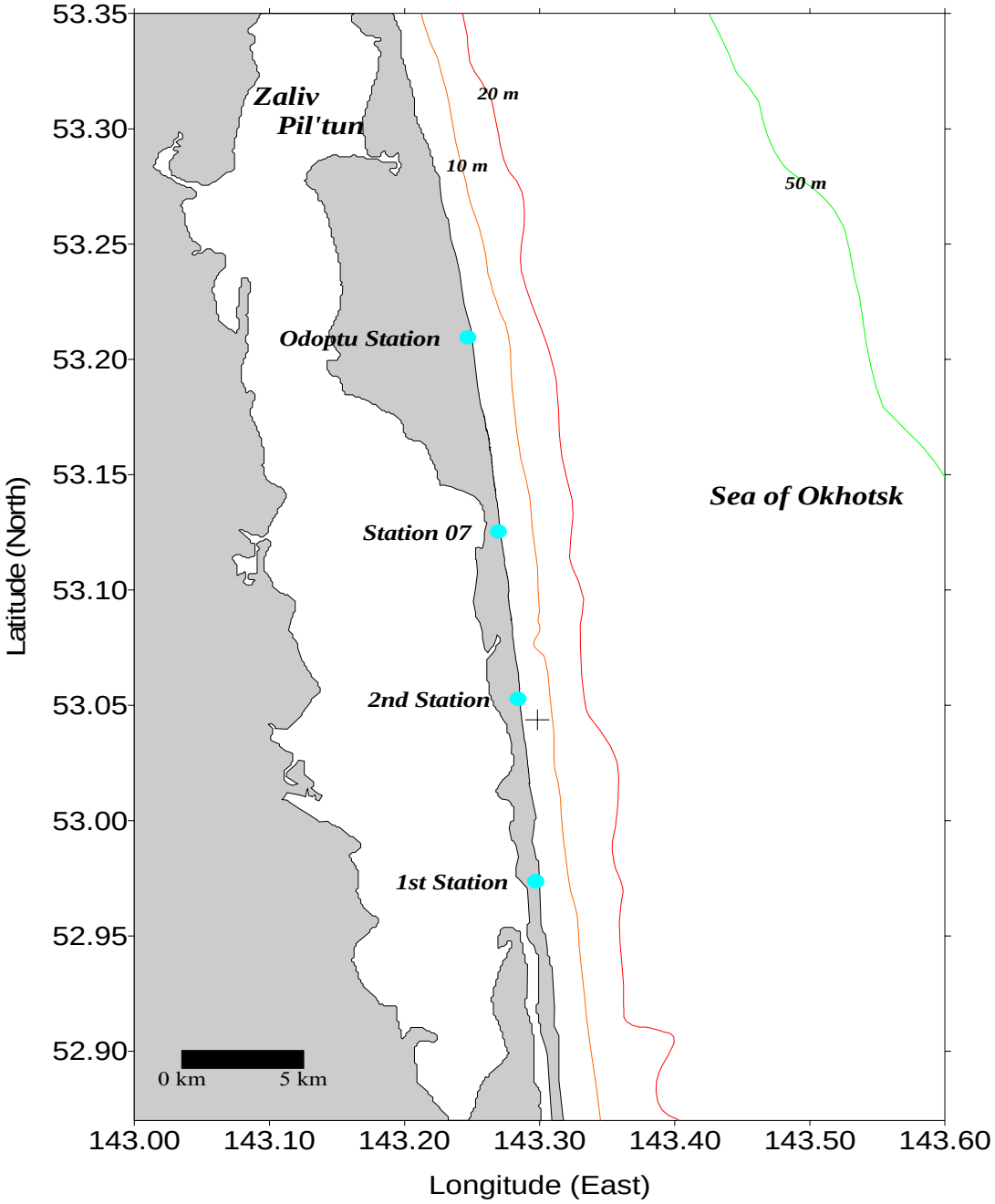
Station: Station 07
Date: 01 September 2003
Number Scans: 2



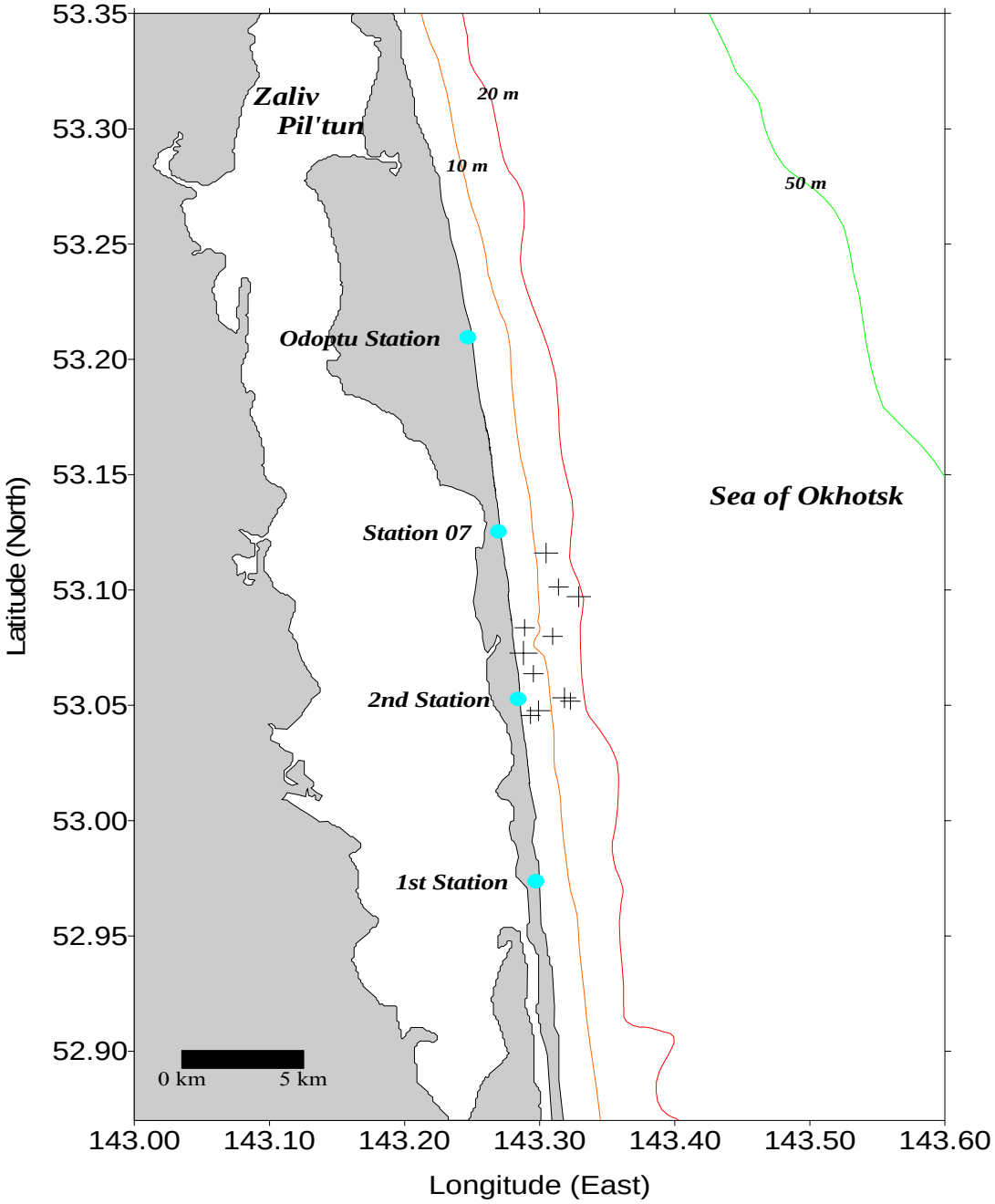
Station: Odoptu Station
Date: 02 September 2003
Number Scans: 2



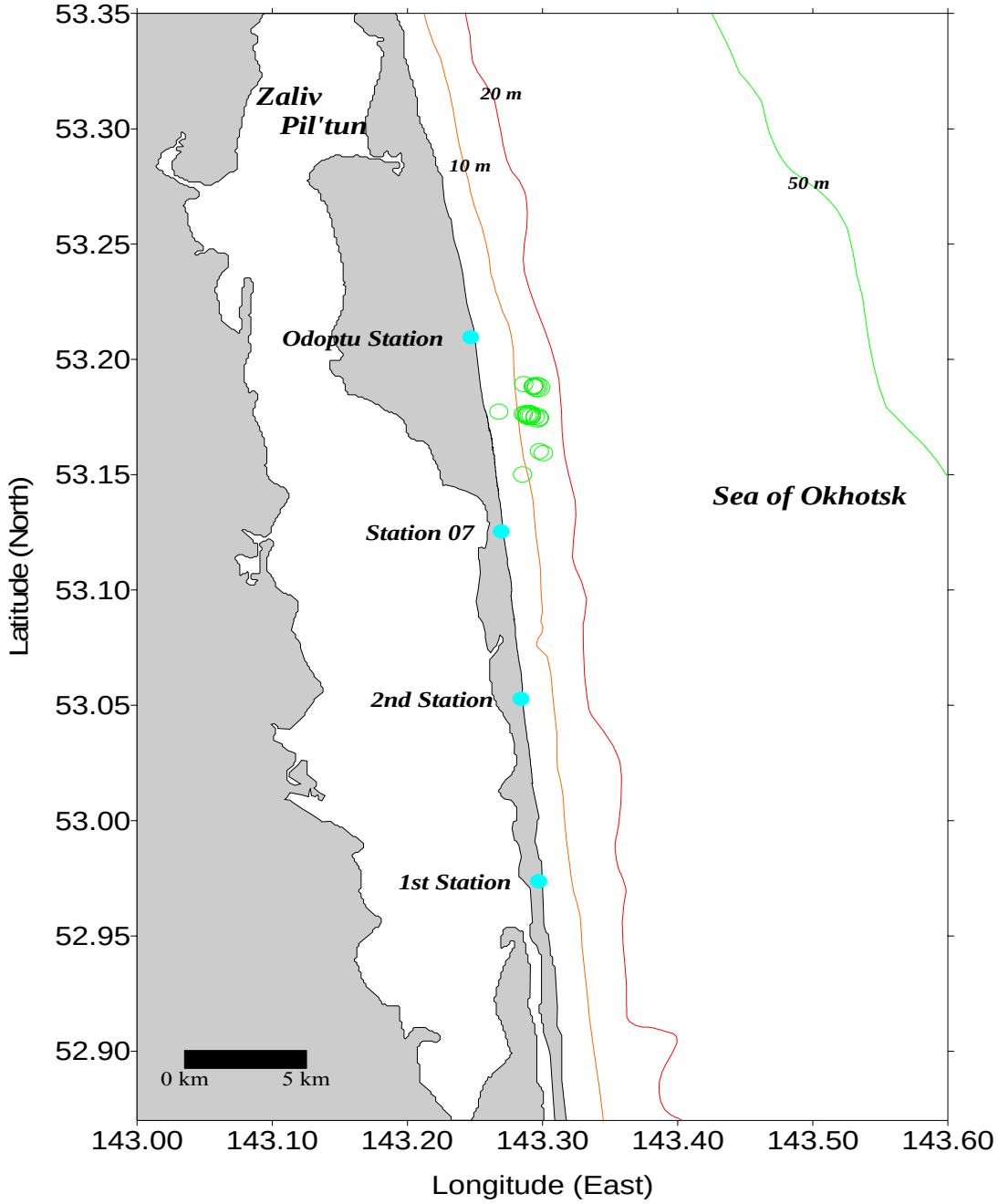
Station: 1st Station
Date: 03 September 2003
Number Scans: 11



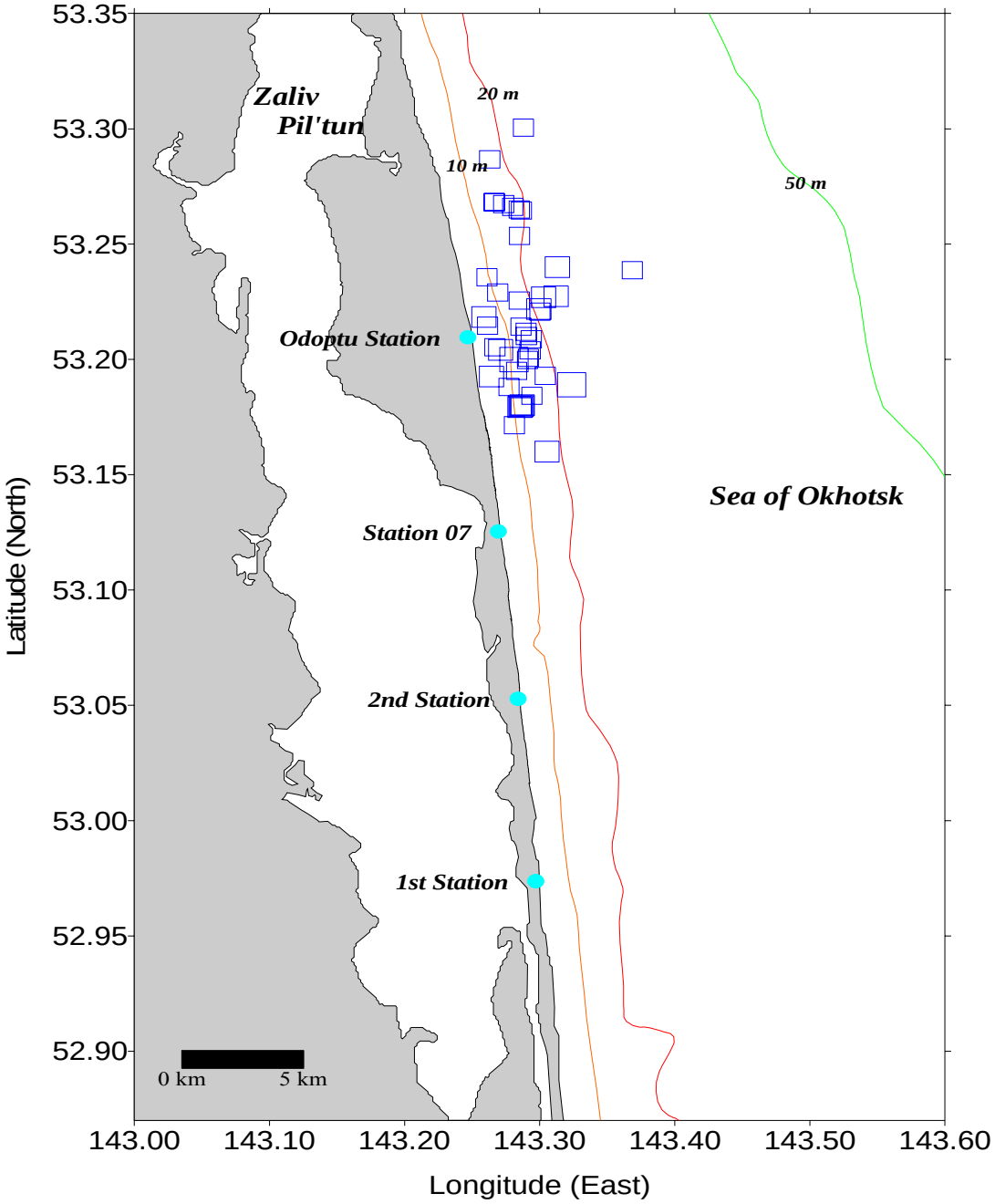
Station: 2nd Station
Date: 04 September 2003
Number Scans: 5



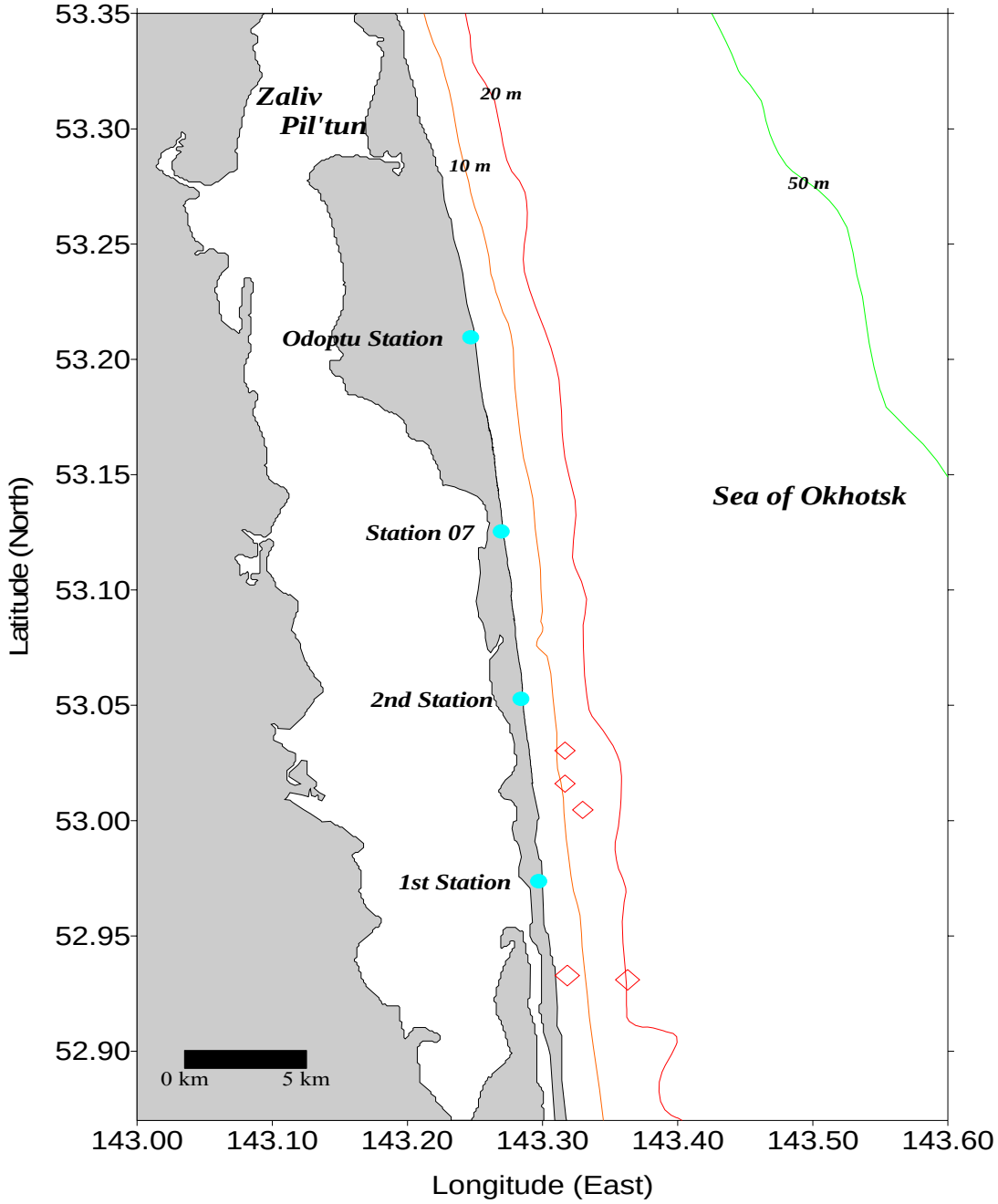
Station: 2nd Station
Date: 05 September 2003
Number Scans: 8



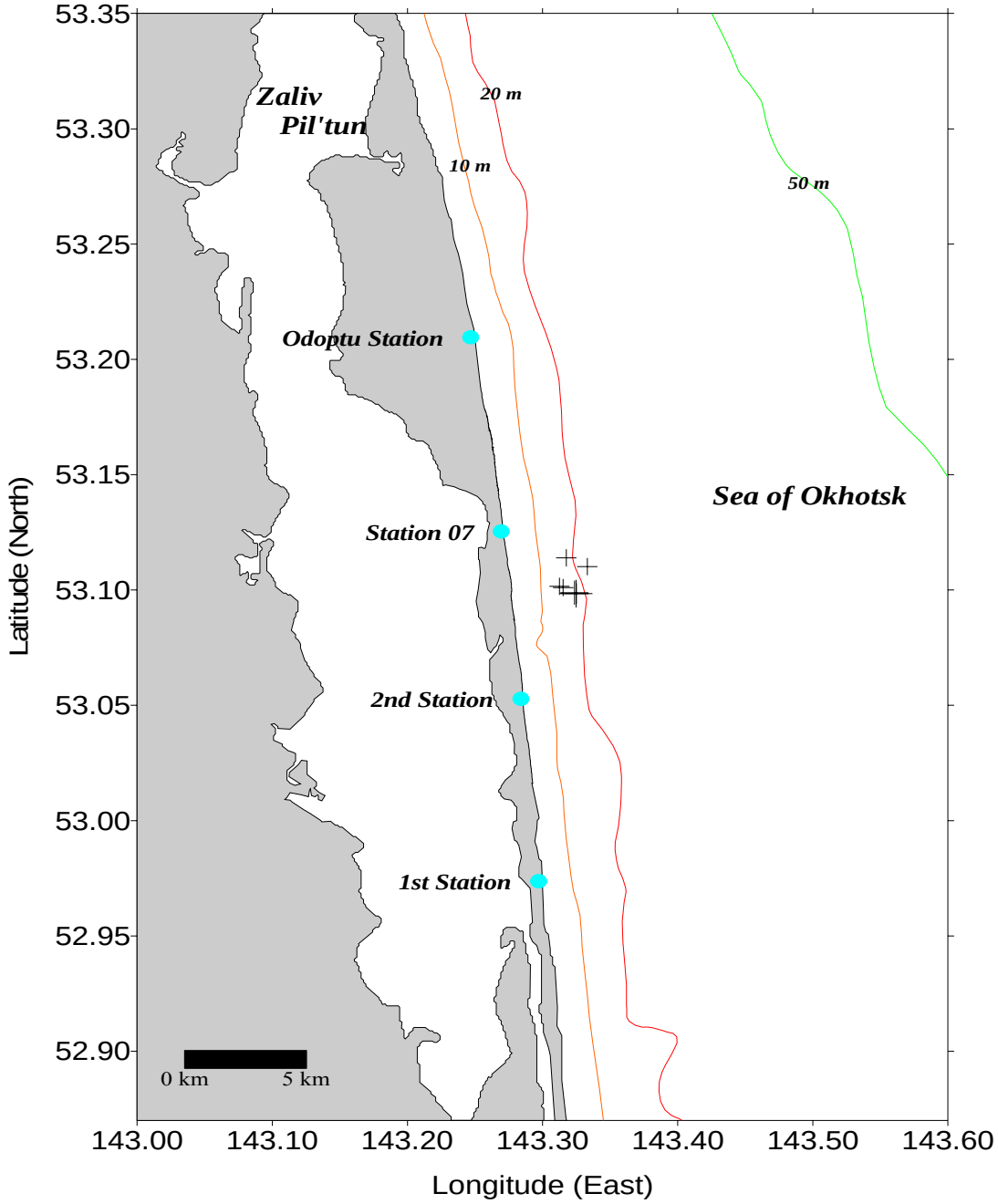
Station: Station 07
Date: 06 September 2003
Number Scans: 9



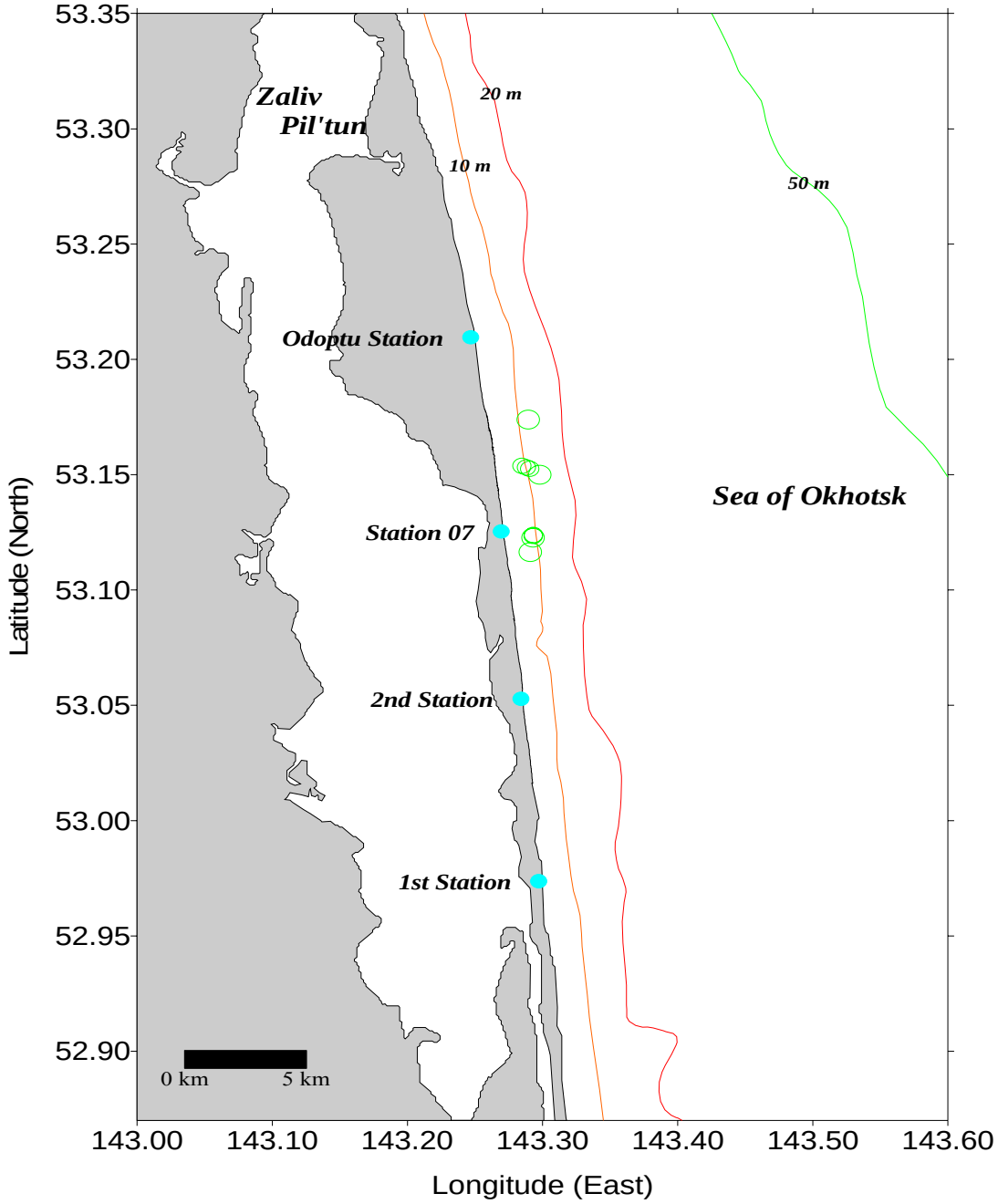
Station: Odoptu Station
Date: 07 September 2003
Number Scans: 7



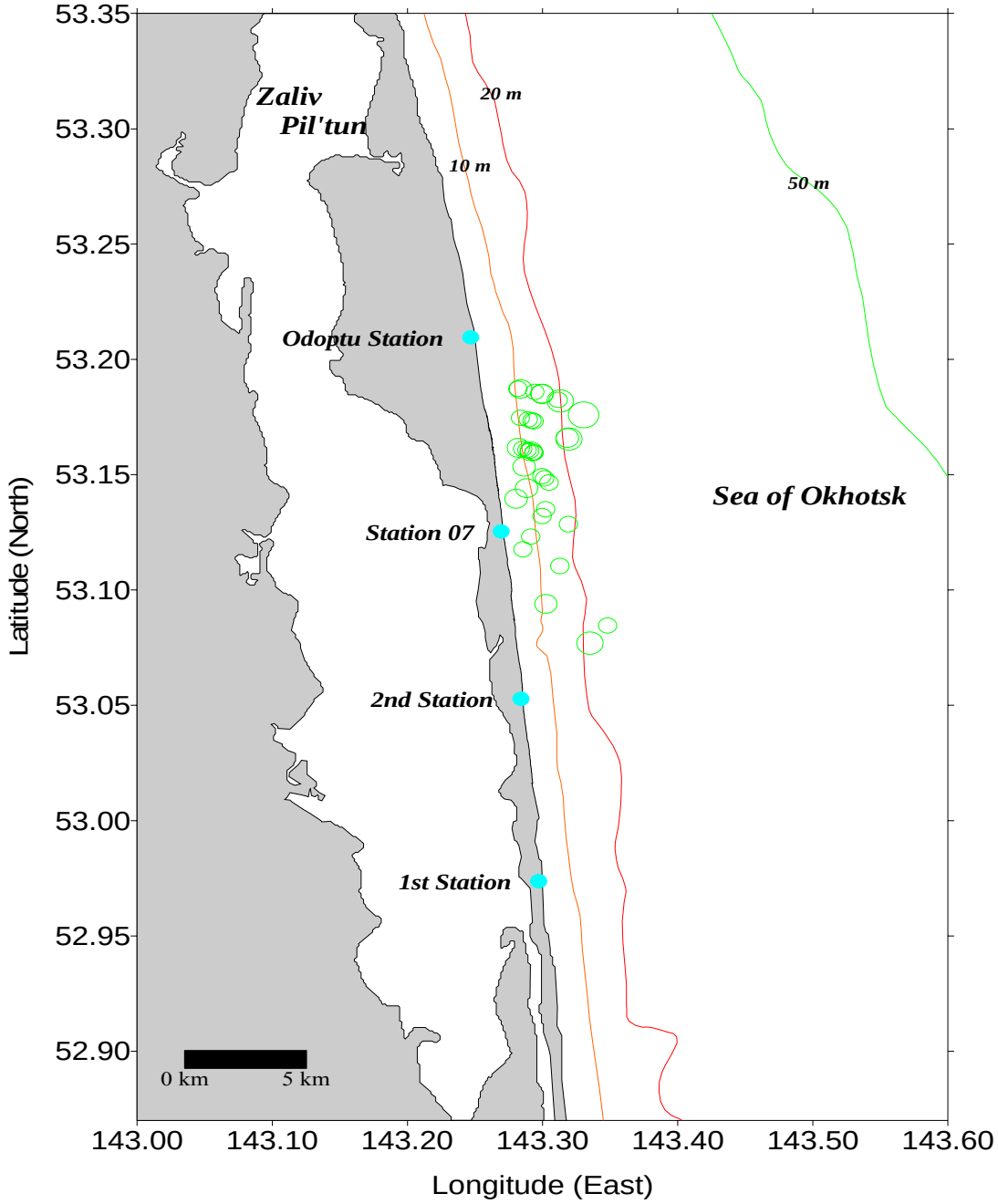
Station: 1st Station
Date: 08 September 2003
Number Scans: 9



Station: 2nd Station
Date: 09 September 2003
Number Scans: 3



Station: Station 07
Date: 12 September 2003
Number Scans: 2



Station: Station 07
Date: 13 September 2003
Number Scans: 7